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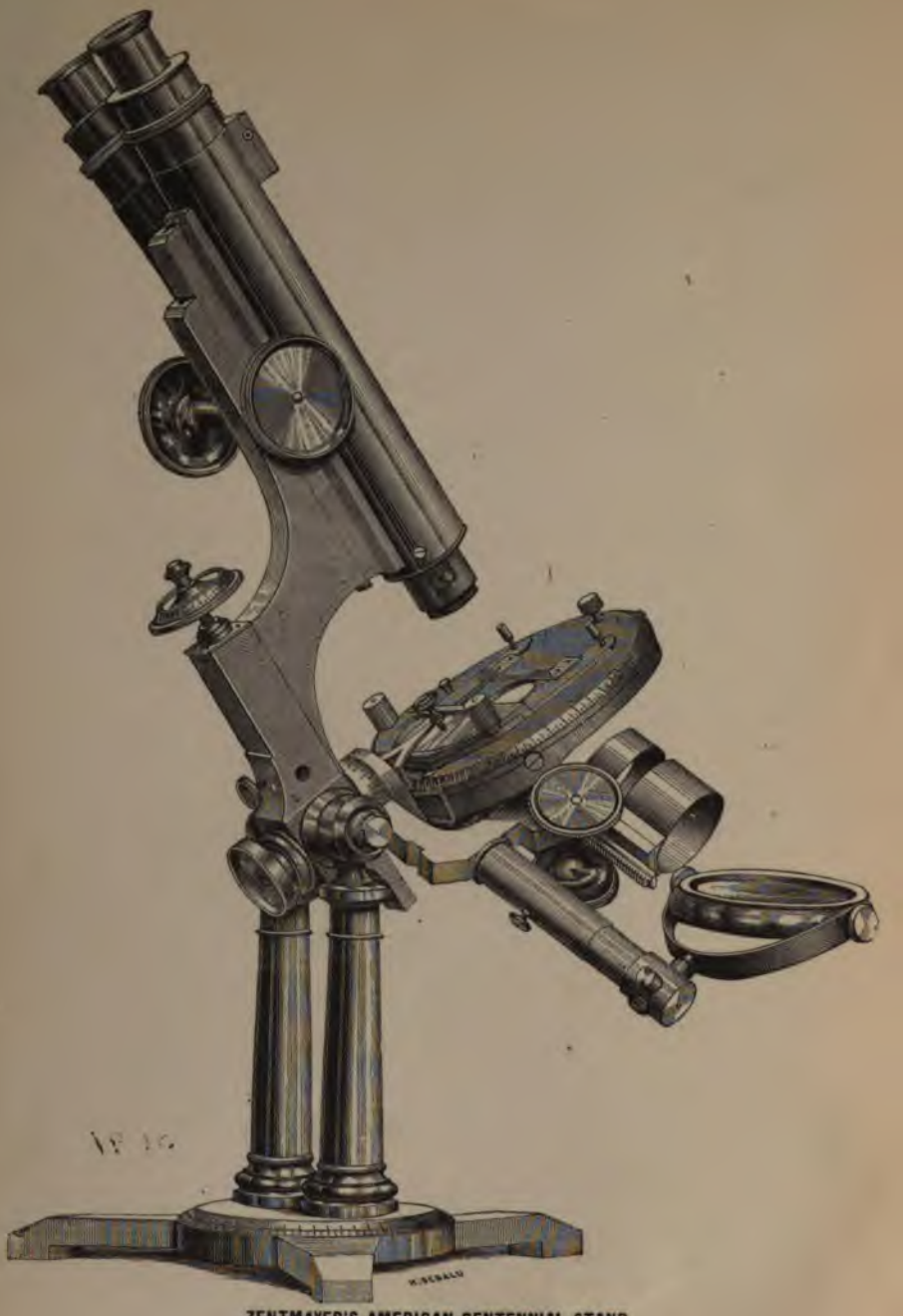

ZENTMAYER'S AMERICAN CENTENNIAL STAND

THE

MICROSCOPIST:

A

MANUAL OF MICROSCOPY,

AND

COMPENDIUM OF THE MICROSCOPIC SCIENCES; MICRO-MINERALOGY, MICRO-CHEMISTRY, BIOLOGY, HISTOLOGY, AND PRACTICAL MEDICINE.

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BY

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RESPECTFULLY DEDICATED

TO THE

SAN FRANCISCO MICROSCOPICAL SOCIETY,

AS A TESTIMONY

TO THE

ZEAL AND INDUSTRY OF ITS MEMBERS

IN

THE PROSECUTION

OF

MICROSCOPIC SCIENCE.

PREFACE.

THE first and second editions of this work, in 1851 and 1853, were intended to furnish a manual on the use of the microscope for physicians and naturalists. The third and present editions aim to be also a compendium of the microscopic sciences, but as microscopy reaches its climax in practical medicine this branch of study receives the largest attention. Matters of mere curiosity have been but briefly referred to, while every necessary fact or principle relating to the microscope has been carefully stated and classified.

By the liberality of the publishers, the chapters on the use of the microscope in Pathology, Diagnosis, and Etiology, which have been added to this edition, have been largely illustrated with woodcuts from Rindfleisch.

The Index and Glossary have been combined in this edition so as to be a source of valuable information, and notices of recent additions to the microscope, together with the genera of microscopic plants, have been given in an Appendix.

No pains have been spared to render this manual a useful companion to the student of Nature, and an aid to the progress of real science.

July, 1880.

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THE MICROSCOPIST.

CHAPTER I.

HISTORY AND IMPORTANCE OF MICROSCOPY.

THE term microscopy, meaning the use of the microscope, is also applied to the knowledge obtained by this instrument, and in this sense is commensurate with a knowledge of the minute structure of the universe, so far as it may come under human observation. Physics and astronomy treat of the general arrangement and motions of masses of matter, chemistry investigates their constitution, and microscopy determines their minute structure. The science of histology, so important to anatomy and physiology, is wholly the product of microscopy, while this latter subject lends its aid to almost every other branch of natural science.

To the student of physical phenomena this subject unfolds an amazing variety developed from most simple beginnings, while to the Christian philosopher it gives the clearest evidence of that Creative Power and Wisdom before whom great and small are terms without meaning.

In the arts, as well as in scientific investigations, the microscope is used for the examination and preparation of delicate work. The jeweller, the engraver, and the miner find a simple microscope almost essential to their employments. This application of the magnifying power of lenses was known to the ancients, as is shown by the glass lens

found at Nineveh, and by the numerous gems and tablets so finely engraved as to need a magnifying glass to detect their details.

In commerce, the microscope has been used to detect adulterations in articles of food, drugs, and manufactures. In a single year $60,000 worth of adulterated drugs was condemned by the New York inspector, and, so long as selfishness is an attribute of degraded humanity, so long will the microscope be needed in this department.

In agriculture and horticulture microscopy affords valuable assistance. It has shown us that mildew and rust in wheat and other food-grains, the "potato disease," and the "vine disease," are dependent on the growth of minute parasitic fungi. It has also revealed many of the minute insects which prey upon our grain-bearing plants and fruit trees. The damage wrought by these insects in the United States alone has been estimated by competent observers as not less than three hundred millions of dollars in each year. The muscardine, which destroys such large numbers of silk-worms in France and other places, is caused by a microscopic fungus, the *Botrytis bassiana*.

The mineralogist determines the character of minute specimens or of thin sections of rock, and the geologist finds the nature of many fossil remains by their magnified image in the microscope.

The chemist recognizes with this instrument excessively minute quantities and reactions which would otherwise escape observation. Dr. Wormley shows that microchemical analysis detects the reaction of the 10,000th to the 100,000th part of a grain of hydrocyanic acid, mercury, or arsenic, and very minute quantities of the vegetable alkaloids may be known by a magnified view of their sublimates. The micro-spectroscope promises still more wonderful powers of analysis by the investigation of the absorption bands in the spectra of different substances.

In biology the wonderful powers of the microscope find

their widest range. If we see not life itself, we see its first beginnings, and the process of its development or manifestation. If we see not Nature in her undress, we trace the elementary warp and woof of her mystic drapery.

In vegetable and animal physiology we see, by its means, not only the elementary unit—the foundation-stone of the building—but also chambers and laboratories in the animated temple, which we should never have suspected—tissues and structures not otherwise discoverable—not to speak of species innumerable which are invisible to the naked eye.

In medical science and jurisprudence the contributions of microscopy have been so numerous that constant study in this department is needed by the physician who would excel or even keep pace with the progress of his profession. Microscopy may be truly called the guiding genius of medical science.

Even theology has its contribution from microscopy. The teleological view of nature, which traces design, receives from it a multitude of illustrations. In this department the war between skeptical philosophy and theology has waged most fiercely; and if the difference between living and non-living matter may be demonstrated by the microscope, as argued by Dr. Beale and others, theology sends forth a pæan of victory from the battlements of this science.

The attempts made by early microscopists to determine ultimate structure were of but little value from the imperfections of the instruments employed, the natural mistakes made in judging the novel appearances presented, and the treatment to which preparations were subjected. In late years the optical and mechanical improvements in microscopes have removed one source of error, but other sources still remain, rendering careful attention to details and accurate judgment of phenomena quite essential. Careful manipulation and minute dissection require a knowledge

of the effects of various physical and chemical agencies, a steady hand, and a quick-discerning eye. Above all, microscopy requires a cultured mind, capable of readily detecting sources of fallacy, and such a love of truth as enables a man to free himself from all preconceived notions of structure and from all bias in favor of particular theories and analogies. What result is it possible to draw from the observations of those who boil, roast, macerate, putrefy, triturate, and otherwise injure delicate tissues, except for the purpose of isolating special structures or learning the effects of such agencies? Yet many of the phenomena resulting from such measures have been described as primary, and theories of development have been proposed on the basis of such imperfect knowledge.

Borelli (1608–1656) is considered to be the first who applied the microscope to the examination of animal structure. Malpighi (1661) first witnessed the actual circulation of the blood, which demonstrated the truth of Harvey's reasoning. He also made many accurate observations in minute anatomy. Lewenhoeck, Swammerdam, Lyonet, Lieberkuhn, Hewson, and others, labored also in this department. When we remember that these early laborers used only simple microscopes, generally of their own construction, we must admire their patient industry, skilful manipulation, and accurate judgment. In these respects they are models to all microscopists.

Within the last quarter of a century microscopic observers may be numbered by thousands, and some have attained an eminent reputation. At the present day, in Germany, England, France, and the United States, the most careful and elaborate investigations are being made, older observations are repeated and corrected, new discoveries are rapidly announced, and the most hidden recesses of nature are being explored.

It is proposed in this treatise to give such a résumé of microscopy as shall enable the student in any department

to pursue original investigations with a general knowledge of what has been accomplished by others. To this end a comprehensive view of the necessary instruments and details of the art, or what the Germans call technology, is first given, and then a brief account of the application of the microscope to various branches of science, especially considering the needs of physicians and students of medicine.

CHAPTER II.

THE MICROSCOPE.

The Simple Microscope.—The magnifying power of a glass lens (from *lens*, a lentil; because made in the shape of its seeds) was doubtless known to the ancients, but only in modern times has it been applied in scientific research.

The forms of lenses generally used are the *double convex*, with two convex faces; *plano convex*, with one face flat and the other convex; *double concave*, with two concave faces; *plano-concave*, with one flat and one concave face; and the *meniscus*, with a concave and a convex face.

In the early part of the seventeenth century very minute lenses were used, and even small spherules of glass. Many of the great discoveries of that period were made by these means. A narrow strip of glass was softened in the flame of a spirit-lamp and drawn to a thread, on the end of which a globule was melted and placed in a thin folded plate of brass, perforated so as to admit the light. Some of these globules were so small as to magnify several hundred diameters. Of course, they were inconvenient to use, and larger lenses, ground on a proper tool, were more common.

The magnifying power of lenses depends on a few simple

optical laws, concerning refraction of light, allowing the eye to see an object under a larger visual angle; so that the power of a simple microscope is in proportion to the shortness of its focal length, or the distance from the lens to the point where a distinct image of the object is seen. This distance may be measured by directly magnifying an object with the lens, if it be a small one, or by casting an image of a distant window, candle, etc., upon a paper or wall. The focus of the lens is the point where the image is most distinct. Different persons see objects naturally at different distances, but ten inches is considered the average distance for the minimum of distinct vision. A lens, therefore, of two inches focal length, magnifies five diameters; of one inch focus, ten diameters; of one-half inch, twenty diameters; of one-eighth inch, eighty diameters; etc.

Simple microscopes are now seldom used, except as hand magnifiers, or for the minute dissection and preparation of objects. They are used for the latter purpose, when suitably mounted with a convenient arm, mirror, etc., because of the inconvenience of larger and otherwise more perfect instruments.

Single lenses, of large size, are also used for concentrating the light of a lamp on an object during dissection, or on an opaque object on the stage of a compound microscope.

There are imperfections of vision attending the use of all common lenses, arising from the spherical shape of the surface of the lens, or from the separation of the colored rays of light when passing through such a medium. These imperfections are called respectively spherical and chromatic aberration. To lessen or destroy these aberrations, various plans have been proposed by opticians. For reducing spherical aberration, Sir John Herschel proposed a doublet of two plano-convex lenses, whose focal lengths are as 2.3 to 1, with their convex sides together;

and Mr. Coddington invented a lens in the form of a sphere, cut away round the centre so as to assume the shape of an hour-glass. This latter, in a convenient setting, is one of the best pocket microscopes. Dr. Wollaston's doublet consists of two plano-convex lenses, whose focal lengths are as 1 to 3, with the plane sides of each and the smallest lens next the object. They should be

Fig. 1.

Holland's Triplet.

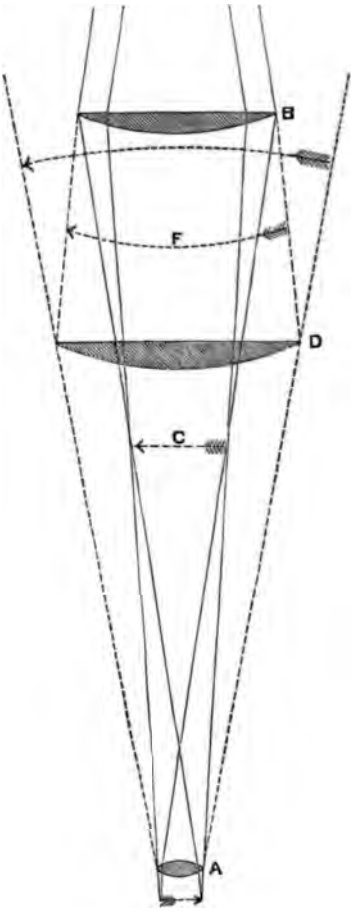
about the difference of their focal lengths apart, and a diaphragm or stop—an opaque screen with a hole in it—placed just behind the anterior lens. This performs admirably, yet has been further improved by Mr. Holland by making a triplet of plano-convex lenses (Fig. 1), with the stop between the upper lenses.

The Compound Microscope consists essentially of two convex lenses, placed some distance apart, so that the image made by one may be magnified by the other. These are called the object-glass and the eye-glass. In Fig. 2, A is the object-glass, which forms a magnified image at C, which is further enlarged by the eye-glass B. An additional lens, D, is usually added, to enlarge the field of view. This is called the field-glass. Its office, as in the figure, is to collect more of the rays from the object-glass and form an image at F, which is viewed by the eye-glass.

Owing to chromatic aberration, an instrument of this kind is still imperfect, presenting rings of color round the edge of the field of view as well as at the edge of the magnified image of an object, together with dimness and

confusion of vision. This may be partly remedied by a small hole or stop behind the object-glass, which reduces the aperture to the central rays alone, yet it is still un-

Fig. 2.



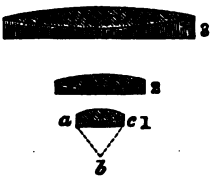
Compound Microscope.

satisfactory. Some considerable improvement may result from using Wollaston's doublet as an object-glass, but the

achromatic object-glasses now supplied by good opticians leave nothing to be desired.

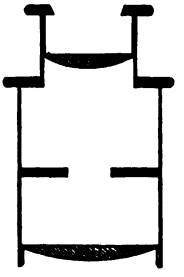
Object-glasses.—A general view of an achromatic object-glass is given in Fig. 3. It is a system of three pairs of lenses, 1, 2, 3, each composed of a double convex of crown glass and a plano-concave of flint. *a*, *b*, *c*, represents the angle of aperture, or the cone of rays admitted. It is unnecessary to consider the optical principles which underlie this construction. Different opticians have different formulæ and propose various arrangements of lenses, and there is room for choice among the multitude of microscopes presented for sale. For high powers, the German

FIG. 3.



Achromatic Object-glass.

FIG. 4.



Huygenian Eye-piece.

and French opticians have lately proposed a principle of construction which is known as the immersion system. It consists in the interposition of a drop of water between the front lens of the objective and the covering glass over the object. This form of object-glass is coming into general use. For the more perfect performance of an objective, it is necessary that it should be arranged for correcting the effect of different thicknesses of covering glass. This is accomplished by a fine screw movement, which brings the front pair of lenses (1, Fig. 3) nearer or further from the object. In this way the most distinct and accurate view of an object may be obtained.

Eye-pieces.—The eye-piece usually employed is the Huygenian, or negative eye-piece (Fig. 4). This is composed of two plano-convex lenses, with their plane sides next the eye. Their focal lengths are as 1 to 3, and their distance apart half the sum of their focal distances. Several of these, having different magnifying powers, are supplied with good microscopes. It is best to use a weak eye-piece, increasing the power of the instrument by stronger objectives when necessary. Kellner's eye-piece has the lens next the eye made achromatic. The periscopic eye-piece of some of the German opticians has both lenses double convex. This gives a larger field of view with some loss of accurate definition. For high powers, I have used a strong meniscus in place of the lower lens in the Huygenian eye-piece. Dr. Royston Pigott has suggested improvements in eye-pieces by using an intermediate Huygenian combination, reversed, between the objective and ordinary eye-piece. This gains power, but somewhat sacrifices definition. Still better, he has proposed an aplanatic combination, consisting of a pair of slightly overcorrected achromatic lenses, mounted midway between a low eye-piece and the objective. This has a separating adjustment so as to traverse two or three inches. The focal length of the combination varies from one and a half to three-fourths of an inch. The future improvement of the microscope must be looked for in this direction, since opticians seem to have approached the limit of perfection in high power objectives, some of which have been made equivalent to $\frac{1}{80}$th or $\frac{1}{100}$th of an inch focal length. As an amplifier, I have used a double concave lens of an inch in diameter and a virtual focus of one and a half inches between the object-glass and the eye-piece. If the object-glass be a good one, this will permit the use of a very strong eye-piece with little loss of defining power, and greatly increase the apparent size of the object.

Mechanical Arrangements.—The German and French opticians devote their attention chiefly to the excellence of their glasses, while the mechanical part of their instruments is quite simple, not to say clumsy. They seem to proceed on the principle that as little as possible should be done by mechanism, which may be performed by the hand. It is different with English and American makers, some of whose instruments are the very perfection of mechanical skill. The disparity in cost, however, for instruments of equal optical power is quite considerable.

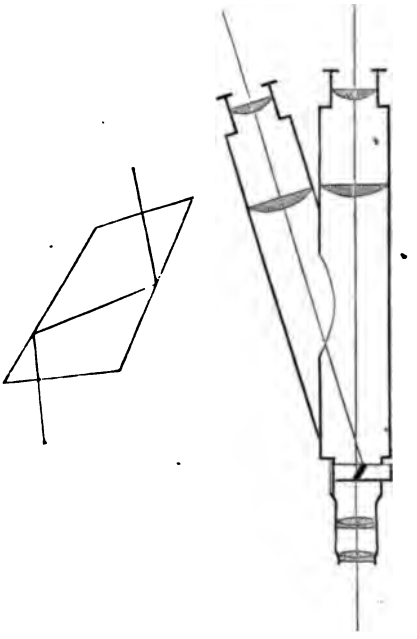
Certain mechanical contrivances are essential to every good instrument. The German and French stands are usually vertical, but it is an advantage to have one which can be inclined in any position from vertical to horizontal. There should be steady and accurate, coarse and fine adjustments for focussing; a large and firm stage with ledge, etc., and with traversing motions, so as to follow an object quickly, or readily bring it into the field of view; also a concave and plane mirror with universal joints, capable of being brought nearer or farther from the stage, or of being turned aside for oblique illumination. Steadiness, or freedom from vibration, is of the utmost importance in the construction, since every unequal vibration will be magnified by the optical power of the instrument.

Among so many excellent opticians it would be impossible to give a complete list of names whose workmanship is wholly reliable, yet among the foremost may be mentioned Tolles, of Boston; Wales, of Fort Lee, N. J.; Grunow, of New York; and Zentmayer, of Philadelphia; Powell & Leland, Ross and Smith, Beck & Beck, of London; Hartnack and Nachet, of Paris; Merz, of Munich; and Gundlach, of Berlin. The optical performance of lenses from these establishments is first class, and the mechanical work of their various models good. The finest instruments from these makers, with complete appliances, are quite costly, except the Germans and French, whose ar-

rangements, as we have said, are more simple. Cheaper instruments, however, are made by English and American opticians, some of which are very fine.

Opticians divide microscopes into various classes, according to the perfection of their workmanship or the accessories supplied. The best first-class instruments have

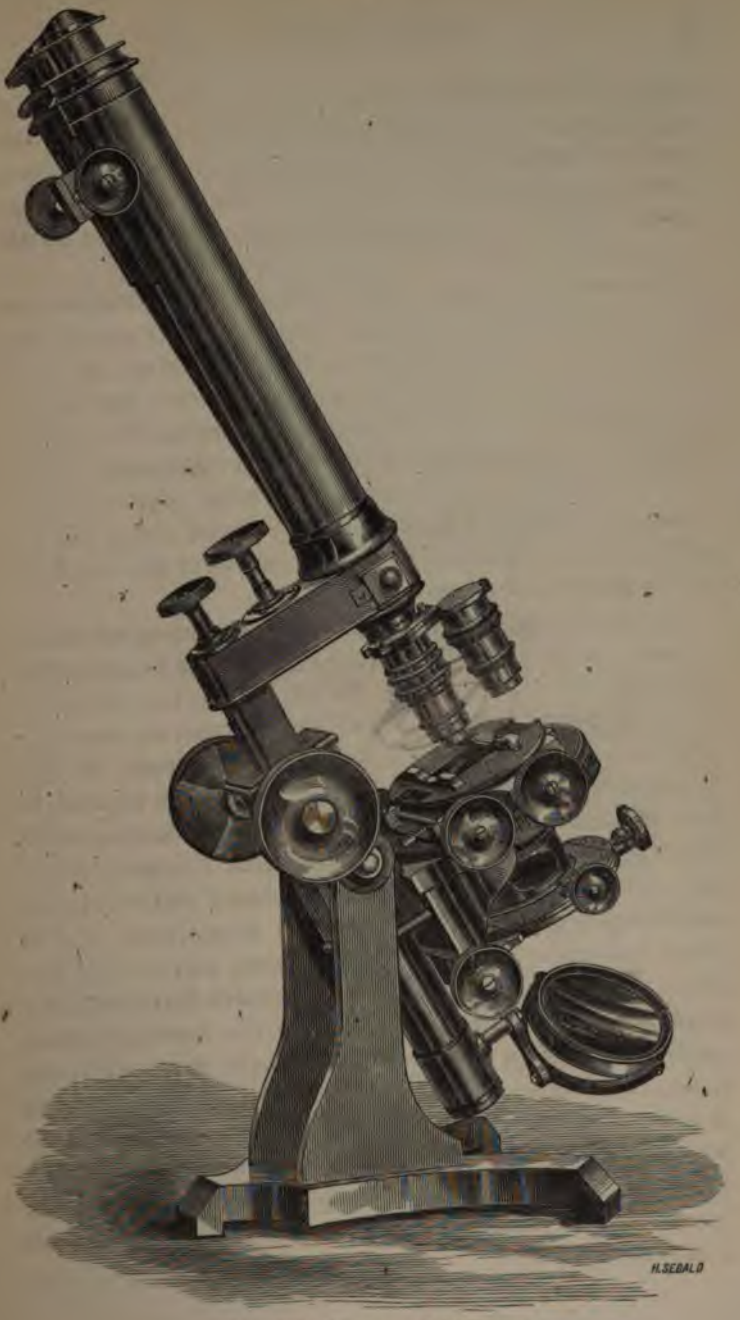
FIG. 5.



Wenham's Prism for the Binocular Microscope.

a great variety of objectives and eye-glasses, mechanical stage with rack-work; a sub-stage with rack for carrying various illuminators: a stand of most solid construction; and every variety of apparatus to suit the want or wish of the observer. They are great luxuries, although not essential to perfect microscopic work. The second class, or students' microscopes, have less expensive stands, but equal optical powers, with first-class instruments. The

Fig. 6.



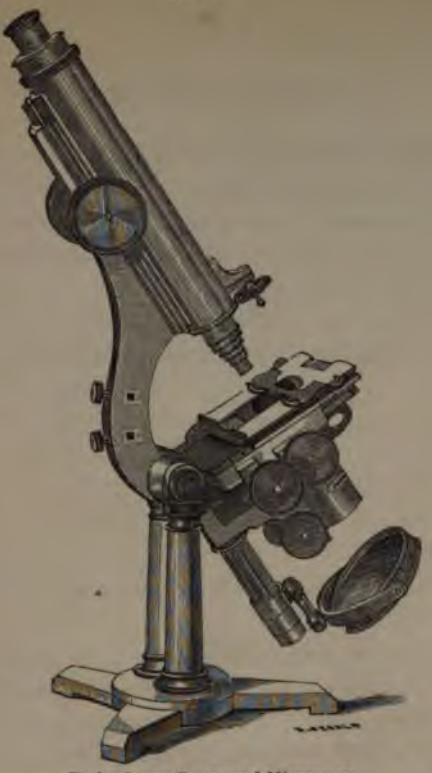
Collins's Harley Binocular Microscope.

third or fourth classes of instruments are intended for popular and educational use, and are fitted not only with stands of more simple workmanship, but with cheaper lenses, although often very good. Some French achromatic objectives, adapted to this class, are suitable for all but the very finest work.

Binocular Microscopes.—The principle of the stereoscope has been applied to the microscope, so as to permit the use of both eyes. The use of such an instrument with low or medium powers is very satisfactory, but is less available with objectives stronger than one-half inch focus. There are two ways of accomplishing a stereoscopic effect in the microscope. The first and most common is by means of Wenham's prism (Fig. 5), placed above the objective, and made to slide so as to transform the binocular into a monocular microscope.

The second mode is to place an arrangement of prisms in the eye piece, so as to refract one-half the image to the right and the other half to the left, which are viewed by the corresponding eyes. In either construction there is a provision made for the variable distance between the eyes of different observers. In the frontispiece is a representation of Zentmayer's grand American microscope, which will afford a good idea of the external appearance of a first class binocular microscope. Students' and third-class microscopes, as before said, are less complicated and of more moderate cost. The mechanical and optical performances of Zentmayer's large instrument leaves scarcely anything to be desired. Instead of the more expensive rack work stage, a simple form, originally invented by Dr. Isaac, of Philadelphia, and copied by Nachet and others, is often employed. It consists of a rotating glass disk, to which is attached a spring, or a V-shaped pair of springs, armed with ivory knobs, which press upon a glass plate in the object carrier. The motion is exceedingly smooth and effective.

Fig. 7.

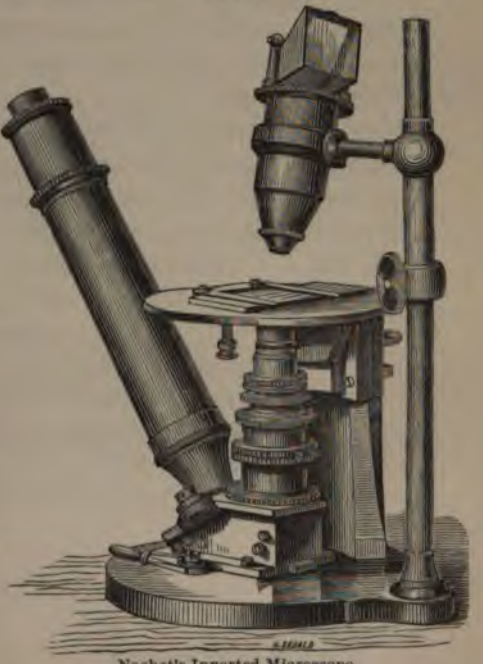


Beck's Large Compound Microscope.

Fig. 8.

Hartnack's Small Model Microscope.

Fig. 9.



Nachet's Inverted Microscope.

Fig. 6 shows Collins's Harley binocular microscope, a good second class instrument.

Fig. 7 represents Beck's large compound miscroscope (monocular); and Fig. 8, Hartnack's small model microscope, with the body made to incline.

Fig. 9, Nachet's inverted microscope, invented by Dr. Lawrence Smith for chemical investigations.

CHAPTER III.

MICROSCOPIC ACCESSORIES.

In addition to the object-glasses, eye-glasses, mirror, and mechanical arrangement of the microscope, to which reference was made in the last chapter, several accessory instruments will be useful and even necessary for certain investigations.

The Diaphragm, for cutting off extraneous light when viewing transparent objects, is generally needed. In some German instruments it consists of a cylinder or tube, whose upper end is fitted with a series of disks having central openings of different sizes. The disk can be adjusted to variable distances from the object on the stage so as to vary its effects. English and American opticians prefer the rotary diaphragm, which is of circular form, perforated with holes of different sizes, and made to revolve under the stage. The gradual reduction of light can be accomplished by the cylinder diaphragm, since when it is pushed up so as to be near the stage it cuts off only a small part of the cone of rays sent upwards by the concave mirror, but, when drawn downwards, it cuts off more.

Collins's Graduating Diaphragm, which is made with four shutters, moving simultaneously by acting on a lever

handle, so as to narrow the aperture, accomplishes the end most perfectly. (Fig 10.)

FIG. 10.

Collins's New Graduating Diaphragm.

Beck's Iris Diaphragm is a further improvement of this sort.

Condensers.—The loss of light resulting from the employment of high powers has led to several plans for condensing light upon the object. Sometimes a plano-convex lens, or combination of lenses, is made to slide up and down under the stage. A *Kellner's eye piece*, or some

FIG. 11.

Smith and Beck's Achromatic Condenser.

similar arrangement, especially if fitted with a special diaphragm, containing slits and holes, some of the latter having central stops, is of very great use. First-class instruments are fitted up with *achromatic condensers* (Fig. 11), carrying revolving diaphragms, some of whose aper-

tures are more or less occupied by stops, or solid disks, so as to leave but a ring of space for light to pass through. The effect of these annular diaphragms is similar to an apparatus for oblique illumination.

The *Webster condenser* is similar in its optical parts to the Kellner eye-piece, and is provided with a diaphragm plate, with stops for oblique illumination, as well as a

FIG. 12.

Webster's Condenser, with Graduating Diaphragms.

graduating diaphragm for the regulation of the central aperture. This is a most useful accessory. (Fig. 12.)

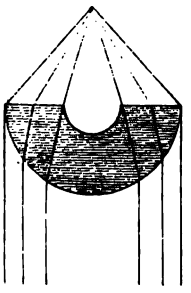
Oblique Illuminators —Certain fine markings on transparent objects can scarcely be made out by central illumination, but require the rays to come from one side, so as to throw a shadow. Sometimes this is well accomplished by turning the mirror aside from the axis of the microscope, and sometimes by the use of one of the condensers referred to above. *Amici's prism*, which has both plane and lenticular surfaces, is sometimes used on one side and under the stage, in lieu of the mirror. For obtaining very oblique pencils of light the *double hemispherical condenser* of Mr. Reade has been invented. It is a hemispherical lens of about one and a half inch diameter, with its flat side next the object, surmounted by a smaller lens of the same form, the flat side of which is covered with a thin diaphragm, having an aperture or apertures close to

its margin. These apertures may be V-shaped, extending to about a quarter of an inch from the centre.

If the microscope has a mechanical stage, with rack-work, or is otherwise too thick to permit the mirror to be turned aside for very oblique illumination, *Nachet's prism* will prove of service. I have also contrived a useful oblique illuminator for this purpose, by cementing with Dammar varnish a plano-convex lens on one face of a totally-reflecting prism, and near the upper edge of the other side (at 90°) an achromatic lens from a French triplet. The prism is made to turn on a hinge, so that an accurate pencil of light may fall on the object at any angle desired.

Dark-ground Illuminators.—Some beautiful effects are produced, and the demonstration of some structures aided, by preventing the light condensed upon the object from entering the object-glass. In this way the object appears

FIG. 13.



Nobert's Illuminator.

FIG. 14.

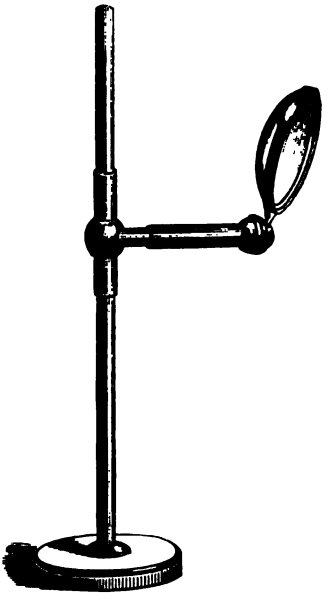
Parabolic Illuminator.

self-luminous on a black ground. For low powers this can be easily done by turning aside the concave mirror as in oblique illumination, or by employing *Nobert's illuminator*, which is a thick plano-convex lens, in the convex

surface of which a deep concavity is made. The plane side is next the object. This throws an oblique light all round the object. A substitute for this, called a *spot lens*, is often used, and differs only from Nobert's in having a central black stop on the plane side instead of a concavity (Fig. 13). A still greater degree of obliquity suitable for high powers must be sought by the use of the *parabolic illuminator* (Fig. 14). This is usually a paraboloid of glass, which reflects to a focus the rays which fall upon its internal surface, while the central rays are stopped.

Illuminators for Opaque Objects.—Ordinary daylight is hardly sufficient for the illumination of opaque objects,

FIG. 15.



Bull's-eye Condenser.

so that microscopists resort to concentrated lamplight, etc. Gas, paraffine, and camphene lamps, have been variously modified for this purpose, but few are better than the Ger-

man student's Argand lamp for petroleum or kerosene oil, as it is called. To concentrate the light from such a source a *condensing lens* is used, either attached to the microscope or mounted on a separate stand. Sometimes a *bull's-eye condenser* is used for more effective illumination (Fig. 15). This is a large plano-convex lens of short focus, mounted on a stand. For such a lens the position of least spherical aberration is when its convex side is towards parallel rays; hence, in daylight, the plane side should be next the object. But, if it is desired to render the diverg-

FIG. 16.

Parabolic Speculum.

ing rays of a lamp parallel, the plane side should be next the lamp, and rather close to it. The use of this condenser will also commend itself, when used as last referred to, in microscopic dissection. It will throw a bright light from the lamp directly on the trough, watch-glass, etc., in which the specimen is being prepared. The *Lieberkuhn*, or a concave speculum attached to the object-glass, and reflecting the light from the mirror directly upon the object, is one of the oldest contrivances for the illumination of opaque objects; but the most convenient instrument is the *parabolic speculum* (Fig. 16), a side mirror with

a parabolic surface attached to the objective. For high powers, a lateral aperture above the objective has been made to throw the light down through the object-glass itself by means of a small reflector, as devised by Prof. Smith, or a disk of thin glass, as in *Beck's vertical illuminator*. This latter is attached to an adapter interposed between the objective and the body of the microscope.

Instruments for Measuring and Drawing Objects.—Screw micrometers are sometimes used with the microscope, as with the telescope, for the measurement of objects; but the less expensive and simpler glass micrometers have generally superseded them. The latter are of two sorts, the stage and the ocular micrometer. The *stage micrometer* is simply a glass slide, containing fine subdivisions of the inch, line, etc., engraved by means of a diamond point. In case the rulings are $\frac{1}{100}$ths and $\frac{1}{1000}$ths of an inch, it is evident that an object may be measured by comparison with the divisions; yet, in practice, it is found inconvenient to use an object with the stage micrometer in this way, and it will be found better to combine its use with that of the drawing apparatus, as hereafter described. The ocular, or *eye-piece micrometer*, is a ruled slip of glass in the eye-piece. Its value is a relative one, depending on the power of the objective and the length of the microscope tube. By comparing the divisions with those of the stage micrometer their value can be readily ascertained. Thus, if five spaces of the eye-piece micrometer cover one space of the stage micrometer, measuring $\frac{1}{1000}$th of an inch, their value will be $\frac{1}{200}$th of an inch each.

Different standards of measurement are used in different countries. English and American microscopists use the inch. In France, and generally in Germany, the Paris line or the millimetre is used. The millimetre is 0.4433 of a Paris line and 0.4724 of an English line ($\frac{1}{12}$th of an inch).

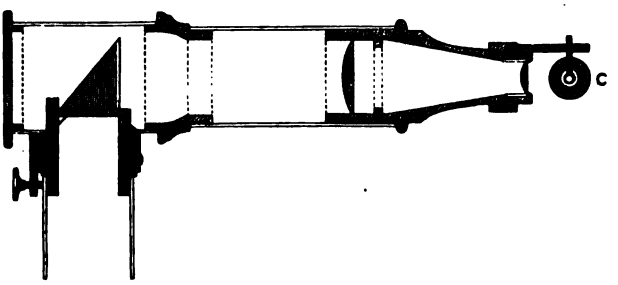
In the French system the fundamental unit is the metre,

which is the ten-millionth part of the quadrant of the meridian of Paris. The multiples are made by prefixing Greek names of numbers, and the subdivisions by prefixing Latin names. Thus, for decimal multiples, we have *deco*, *hecto*, *kilo*, *and myrio;* and, for decimal subdivisions, *deci*, *centi*, and *milli*. The following may serve for converting subdivisions of the metre into English equivalents:

A millimetre equals 0.03937 English inches.
A centimetre " 0.39371 "
A decimetre " 3.93708 "
One inch = 2.539954 centimetres, or 25.39954 millimetres.

For drawing microscopic objects the *camera lucida* will be found useful. This is a small glass prism attached to the eye-piece. The microscope is inclined horizontally,

FIG. 17.



Oberhauser's Drawing Apparatus.

and the observer, looking into the prism, sees the object directly under his eye, so that its outlines may be drawn on a piece of paper placed on the table. Some practice, however, is needed for satisfactory results. For the upright stands of German and French microscopes, the camera lucida of Chevalier & Oberhauser is available. This is a prism in a rectangular tube, in front of which is the eye-piece, carrying a small glass prism (c, Fig. 17), surrounded

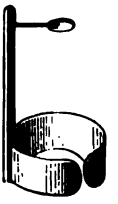
by a black metal ring. A paper placed beneath is visible through the opening in the ring, and the image reflected by the prism upon it can be traced by a pencil. It is necessary to regulate the light so that the point of the pencil may be seen.

Dr. Beale has recommended, in lieu of the camera lucida, a piece of slightly tinted plate glass (Fig. 18), placed in a short tube over the eye-piece at an angle of 45°. This is a cheap and effective plan. A similar purpose is served

FIG. 18.

Beale's Tint-glass Camera.

FIG. 19.



Sœmmering's Steel Disk.

by a little steel disk, smaller than the pupil of the eye, placed at the same angle (Fig. 19).

The most simple method of measuring objects is to employ one of the above drawing instruments, placing first on the microscope stage an ordinary micrometer, and tracing its lines on the paper. Then the outline of the object can be traced and compared with the lines. The magnifying power of an object-glass can also be readily found by throwing the image of the lines in a stage micrometer upon a rule held ten inches below the eye-piece, looking at the magnified image with one eye and at the rule with the other. Dr. Beale strongly urges observers to delineate their own work on wood or stone, since they can do it more exactly and truthfully than the

most skilled artists who are unfamiliar with microscopic manipulation.

Other accessory apparatus, such as a *frog-plate*, for more readily observing the circulation in a frog's foot; an *animalcule cage*, or live box; a *compressorium*, for applying pressure to an object; fishing tubes; watch-glasses; growing-slides, etc., will commend themselves on personal inspection.

For preventing the evaporation of fluids during observation, Recklinghausen invented the *moist chamber* (Fig. 20), consisting of a glass ring on a slide, to which is fastened a tube of thin rubber, the upper end of which is fastened round the microscope tube with a rubber band.

FIG. 20.

Recklinghausen's Moist Chamber.

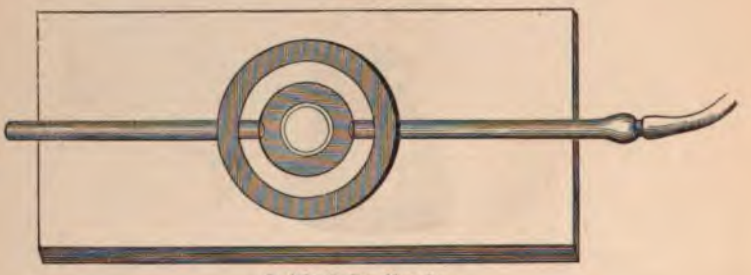
A simpler form of moist chamber may be made by a glass ring cemented on a slide. A few drops of water cautiously put on the inner edge of the ring with a brush, or a little moist blotting-paper may be placed inside. The object (as a drop of frog's blood, etc.) may then be put on a circular thin cover, which is placed inverted on the ring. A small drop of oil round the edge of the cover keeps it air and water-tight.

Somewhat similar to the above is Stricker's *gas chamber* (Fig. 21). On the object-slide is a ring of glass, or putty, with its thin cover. Through this ring two glass tubes are cemented, one of which is connected with a rubber

tube for the entrance of gas, while the other serves for its exit.

For the study of phenomena in the fluids, etc., of warm-blooded animals, we need, in addition to the moist chamber, some way of keeping the object warm. This may be roughly done by a perforated tin or brass plate on the stage, one end of which is warmed by a spirit-lamp. A piece of cocoa butter or wax will show by its melting when the heat is sufficient. Schultze's *warm stage* is a more satisfactory and scientific instrument. It is a brass plate to fit on the stage, perforated for illumination, and connected with a spirit-lamp and thermometer, so that

FIG. 21.



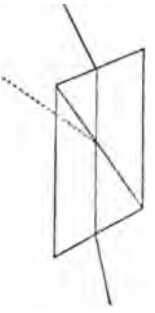
Stricker's Gas Chamber.

the amount of heat may be exactly regulated. Other arrangements have been proposed to admit a current of warm water, or for the passage of electricity through an object while under observation, which are scarcely necessary to describe.

The Polariscope.—The nature and properties of polarized light belong rather to a treatise on optics or natural philosophy than to a work like the present, yet a very brief account may not be out of place. We premise, then, that every ray or beam of common light is supposed to have at least two sets of vibrations, vertical and horizontal. As these vibrations have different properties, the ray when

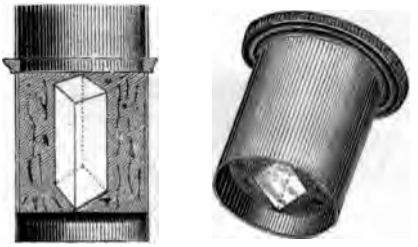
divided is said to be *polarized*, from a fancied resemblance to the poles of a magnet. The division of the vibrations may be effected (*i. e.*, the light may be polarized) in various ways. For the microscope the *polarizer* is a Nichol's prism, composed of a crystal of Iceland spar, which has been divided and again cemented with Canada balsam, so as to throw one of the doubly refracted rays aside from the field of view (Fig. 22). Such a prism is mounted in a short tube and attached to the under side of the stage. In order to distinguish the effects of polarized light, an *analyzer* is also needed. This usually consists of another

FIG. 22.



Nichol's Prism.

FIG. 23.



Polarizer and Analyzer.

similar Nichol's prism, attached either to the eye-piece or just above the objective. The latter position gives a larger field, but the former better definition. Fig. 23 shows the polarizer and the analyzer. The polarizer is improved by the addition of a convex lens next the object. Hartnack has also improved the eye-piece analyzer by adding a graduated disk and vernier.

When the polarizer and analyzer have been put in place, they should be rotated until their polarizing planes are parallel, and the mirror adjusted so as to give the most intense light. If now the polarizing planes are placed at right angles, by turning one of them 90°, the field is ren-

dered dark, and doubly refracting bodies on the stage of the microscope appear either illuminated or in colors. If a polarized ray passes through a doubly refracting film, as of selenite, it forms two distinct rays, the ordinary and the extraordinary ray. Each of these will be of different colors, according to the thickness of the film. If one be red, the other will be green, these colors being complementary. By using the analyzer one of these rays is alternately suppressed, so that on revolving the apparatus the green and red rays appear to alternate at each quarter of a circle. Films of selenite are often mounted so as to revolve between the polarizer and the stage. Darker's *selenite stage* is sometimes used for this purpose (Fig. 24). With such a stage a set of selenites is usually

FIG. 24.

Darker's Selenite Stage.

supplied, giving the blue, purple, and red, with their complementary colors, orange, yellow, and green. By this combination all the colors of the spectrum may be obtained. The selenite disks generally have engraved on them the amount of retardation of the undulations of white light, thus: $\frac{1}{4}$, $\frac{3}{4}$, and $\frac{9}{4}$. If these are placed so that their positive axes (marked PA) coincide, they give the sum of their combined retardations.

The Microspectroscope.—Ordinary spectrum analysis, by determining the number and position of certain narrow lines in the spectra of luminous bodies, called Fraunhofer's

lines, enables the chemist to identify different substances. The object of the microspectroscope is different. It enables us to distinguish substances by the absence of certain rays in the spectrum, or, in other words, to judge of substances by a scientific examination of their color. The color of a body seen with the naked eye is the general impression made by the transmitted light, and this may be the same although the compound rays may differ

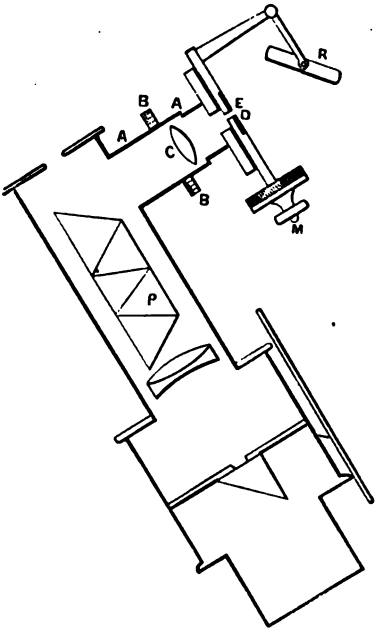
FIG. 25.

The Sorby-Browning Microspectroscope.

greatly, so that colors which seem absolutely alike may be distinguished by their spectra. Many solutions are seen to absorb different colors in very definite parts of the spectrum, forming absorption bands or lines, varying in width and intensity according to the strength of the solution. The instrument usually employed consists of a direct-vision spectrum apparatus attached to the eye piece of the microscope, which shows the principal Fraunhofer

lines by daylight, or a spectrum of the light transmitted by any object in the field of view. A reflecting prism is placed under one-half of the slit of the apparatus so as to transmit from a side aperture a standard spectrum for comparison. In Fig. 25, A is a brass tube carrying the compound direct-vision system of five prisms and an achromatic lens. This tube is moved by the milled head

FIG. 26.



Spectroscope with Micrometer.

B, so as to bring to a focus the different parts of the spectrum. This is important when the bands or lines to be examined are delicate. D is the stage on which objects for comparison are placed. The light passing through them from the mirror I, goes through a side opening to a reflecting prism which covers a part of a slit in the bottom of the tube A. This slit is opened and shut by means of the screws C and H. Fig. 26 shows the internal ar-

rangement of the prisms and lens, together with a micrometer for measuring the position of lines or absorption bands. To use the microspectroscope, remove the tube A, with the prisms, and insert the tube G in the place of the eye-piece of the microscope. With the lowest power object-glass which is suitable, and the slit opened wide by the screw H, the object on the stage of the microscope, illuminated by the mirror or condenser, is brought to a focus, the tube A replaced and adjusted for focus by the screw B, while the slit is regulated by C and H until a well-defined spectrum is seen. To determine the position of the absorption lines, remove the upper cover of the tube A and replace it with that carrying the micrometer represented in Fig. 26. The mirror illuminates a transparent line or cross, whose image is refracted by a lens C, movable by a screw B, and reflected at an angle of 45° from the upper surface of the prisms, so as to be seen upon the spectrum. By means of the micrometer screw M, this is made to move across the spectrum, so that the distance between the lines may be determined. In order to compare the results given by different instruments, the observer should measure the position of the principal Fraunhofer lines in bright daylight, and mark them on a cardboard scale, which may be preserved for reference. By comparing the micrometric measurement of lines in the spectrum of any substance observed by artificial light with such a scale, their position may readily be seen.

In using the microspectroscope some objects require a diaphragm of small size, and others, especially with the 1½ or 2-inch objective, a cap with a hole $\frac{1}{16}$th of an inch in diameter over the end of the microscope, to prevent extraneous light from passing through the tube.

Nose-piece.—For the purpose of facilitating observations with objectives of different powers a revolving nose-piece has been contrived, carrying two, three, or four objectives,

which may be brought quickly into the axis of the instrument.

Object-finders.—It is sometimes tedious to find a small object on a slide, particularly with high powers, and a number of contrivances, as Maltwood's finder, have been proposed for this end. A very simple method, however, may serve. Mark on the stage two crosses, one like the sign of addition +, and the other like the sign of multiplication ×, and, when the object is found, mark the slide to correspond with the marks below. If the stage be a mechanical one it will be necessary to arrange it in the previous position.

Microscopic Photography.—Many European experimenters have succeeded in taking microscopic photographs, but a great advance in this direction has been made under the direction of the medical department of the United States army at Washington. Lieutenant-Colonel Woodward has succeeded in furnishing permanent records of many details of structure, which exhibit the very perfection of art. In a work like the present a full account of the apparatus and methods employed would be out of place. Dr. Beale's *How to Work with the Microscope*, and the reports issued from the Surgeon-General's office at Washington, will give the details.

CHAPTER IV.

USE OF THE MICROSCOPE.

Care of the Instrument.—But little satisfaction will be secured in microscopic work for any length of time without scrupulous care of the lenses, etc., belonging to the instrument, and habits of this kind should be early acquired. When in frequent use the microscope should be

seldom packed away in its case, as a certain necessary stiffness of motion in its various parts might thereby be lessened. Yet it should be kept free from dust and damp. A bell-glass cover, or glass case, or a cabinet which will admit the reception of the instrument in a form ready for immediate use, is desirable. Before using, the condition of objective and eye-piece should be examined as well as of the mirror, and dust or dampness removed. Another examination should be made before the microscope is put away.

Stains on the brass-work may be removed by a linen rag, and dust on the mirror and lenses by a fine camel's-hair brush, or very soft and clean chamois skin. Frequent wiping will injure the polish of the lenses.

The upper surfaces of the lenses in the eye-pieces and the mirror will need the most frequent attention The objectives, if carefully handled and kept in their boxes when not in use, will seldom require cleaning If the front of the objective becomes accidentally wet with fluid it should be at once removed, and, when reagents are used, great care should be taken to prevent contact with the front of the lens.

Care of the Eyes.—Continuous observation, especially by lamplight, and with high powers, has doubtless a tendency to injure the sight. To cease work as soon as fatigue begins is, however, a simple but certain rule for protection. This time will vary greatly, according to the general tone and vigor of the observer. It is also important to use the eyes alternately if a monocular instrument is employed, as otherwise great difference both in the focus and in the sensitiveness of the eyes will result. The habit of keeping the unemployed eye open is a good one, and, though troublesome at first, is not difficult to acquire. It is well to protect the eye from all extraneous light, and to exclude every part of the object except that which is under immediate observation. The diaphragm

will serve this end as well as modify the quality of the light. For very delicate observations a dark shade over the stage, which may be fastened by an elastic ring to the microscope-tube, so as to shut off extraneous light, will be useful.

Table, etc.—The microscopist's work-table should be large and massive, so as to be convenient and free from vibration. Drawers for accessories and materials used in preparing and mounting objects are also desirable, as well as a few bell-glasses for secluding objects from dust. Reagents should always be removed from the table after use and kept in another place.

Light.—Dr. Carpenter has well said, "Good daylight is to be preferred to any other kind of light, but good lamplight is preferable to bad daylight." A clear blue sky gives light enough for low powers, but a dull white cloudiness is better. The direct rays of the sun are too strong, and should be modified by a white curtain, reflection from a surface of plaster of Paris, or, still better, by passing through a glass cell containing a solution of ammonio-sulphate of copper.

Various kinds of lamps have been contrived for microscopic use; among the best are the German and French "student's reading lamps," which burn coal oil or petroleum. It is often useful to moderate such a light by the use of a chimney of blue glass, or by a screen of blue glass between the flame and the object. Dr. Curtis contrived a useful apparatus, consisting of a short petroleum lamp placed in an upright, oblong box. On one side of the box is an opening occupied with blue glass; on another side the opening has ground-glass, as well as a piece colored blue, and a plano-convex lens so placed as to condense the light thus softened to a suitable place on the table.

As a general rule the light should come from the left side, and that position assumed or inclination given to the instrument which is most comfortable to the observer.

English and American microscopists prefer an inclined microscope, while the German and French instruments being usually vertical do not permit this arrangement.

Adjustment.—The details of microscopic adjustments are only to be learned by practice, yet a few directions may be instructive. The selection of the objectives and eye-pieces depends on the character of the object. As a general rule, the lowest powers which will exhibit an object are the best. It is best to use weak eye-pieces with the stronger objectives, yet much depends on the perfection of the glasses employed.

The focal adjustment can be made with the coarse adjustment or quick motion when low powers are employed; but for higher powers the fine adjustment screw is essential. Care must be taken not to bring the objective into close or sudden contact with the thin glass cover over the object, and, in changing object-glasses, the microscope body should be raised from the stage by the coarse adjustment.

The actual distance between the object and object-glass is much less than the nominal focal length, so that the 1 inch objective has a working distance of about $\frac{1}{2}$ an inch, the $\frac{1}{8}$th of about $\frac{1}{40}$th of an inch, while shorter objectives require the object to be covered with the thinnest glass.

Sometimes, in high powers, and especially with immersion-lenses, an adjustment of the object-glass is necessary in order to suit the thickness of the glass cover. With thick covers the individual lenses must be brought nearer to each other, and, with very thin covers, moved farther apart.

If immersion-objectives be employed a drop of water is placed on the glass cover with a glass rod or camel's-hair pencil, and a second drop on the lens. The lens and object are then approximated till the drops flow together and the focus is adjusted. By turning the screw of the objective

and using the fine adjustment the best position will be shown by the sharper and more delicate image of the object.

For other details respecting adjustment the reader is referred to the chapter on Microscopic Accessories.

Errors of Interpretation.—True science is hindered most of all by speculation and false philosophy, which often assume its garb and name, but it is also retarded by imperfect or false observation. It is much less easy to see than beginners imagine, and still less easy to know what we see. The latter sometimes requires an intellect of surpassing endowments. The sources of error are numerous, but some require special caution, and to these we now refer.

The nature of microscopic images causes error from imperfect focal adjustment. We see distinctly only that stratum of an object which lies directly in focus, and it is seldom that all parts of an object can be in focus together. Hence we only recognize at once the outline of an object, but not its thickness, and, as the parts which are out of focus are indistinct, we may readily fall into error. Glasses vary much in this respect. Some have considerable penetrating and defining power even with moderate angular aperture, and are better for general work than those more perfect instruments which give paler images and only reveal their excellencies to the practiced microscopist.

Sometimes the focal adjustment leads to error on account of the reversal of the lights and shadows at different distances. Thus the centres of the biconcave blood-disks appear dark when in focus, and bright when a little within the focus; while the hexagonal elevations of a diatom, as the *Pleurosigma angulatum*, are light when in focus, with dark partitions, and dark when just beyond the focus. From this we gather a means of discrimination, since a convex body appears lighter by raising the microscope, and a concave by lowering it.

The refractive power of the object, or of the medium in which it lies, is sometimes a source of error. Thus a human hair was long thought to be tubular, because of the convergence of the rays of light on its cylindrical convexity. A glass cylinder in balsam appears like a flat band, because of the nearly equal refractive powers of object and medium. The lacunæ and canaliculæ of bone were long considered solid, because of the dark appearance presented on account of the divergence of the rays passing through them. Their penetration with Canada balsam, however, proves them to be cavities. Air-bubbles, from refraction, present dark rings, and, if present in a specimen, seldom fail to attract the first attention of an inexperienced observer. The difference between oil-globules in water and water in oil, or air-bubbles, should be early learned, as in some organized structures oil-particles and vacuoles (or void spaces) are often interspersed. A globule of oil in water becomes darker as the object-glass is depressed, and lighter when raised; while the reverse is the case with water in oil, since the difference of refraction causes the oil particles to act as convex lenses, and those of water like concave lenses.

Other errors arise from the phenomena of motion visible under the microscope. A dry filament of cotton, or other fabric absorbing moisture, will often oscillate and twist in a curious way.

If alcohol and water are mixed, the particles suspended acquire a rapid motion from the currents set up, which continues till the fluids are thoroughly blended. Nearly all substances in a state of minute division exhibit, when suspended in fluid, a movement called the "Brownonian motion," from Dr. Robert Brown, who first investigated it. It is a peculiar, uninterrupted, dancing movement, the cause of which is still unexplained. These movements, as all others, appear more energetic when greatly magnified by strong objectives. It requires care to discriminate

between such motions and the vital or voluntary motions of organized bodies.

The inflection or diffraction of light is another source of error, since the sharpness of outline in an object is thus impaired. The shadow of an opaque object in a divergent pencil of light presents, not sharp, well-defined edges, but a gradual shading off, from which it is inferred that the rays do not pass from the edge of the object in the same line as they come to it. This is in consequence of the undulatory nature of light. When any system of waves meets with an obstacle, subsidiary systems of waves will be formed round the edge of the obstacle and be propagated simultaneously with the original undulations. For a certain space around the lines in which the rays, grazing the edge of the opaque body, would have proceeded, the two systems of undulation will intersect and produce the phenomena of interference. If the opaque body be very small, and the distance from the luminous point proportionally large, the two pencils formed by inflection will intersect, and all the phenomena of interference will become evident. Thus, if the light be homogeneous, a bright line of light will be formed under the centre of the opaque object, outside of which will be dark lines, and then bright and dark lines alternately. If the light be compound solar light, a series of colored fringes will be formed. In addition to the results of inflection, oblique illumination at certain angles produces a double image, or a kind of overlying shadow, sometimes called the "diffraction spectrum," although due to a different cause. No rules can be given for avoiding errors from these optical appearances, but practice will enable one to overcome them, as it were, instinctively.

Testing the Microscope.—The defining power of an instrument depends on the correction of its spherical and chromatic aberrations, and excellence may often be obtained with objectives having but a moderate angle of

aperture. It may be known by the sharp outline given to the image of an object, which is not much impaired by the use of stronger eye pieces.

Resolving power is the capability an instrument has of bringing out the fine details of a structure, and depends mainly on the angle of aperture of the objective, or the angle formed by the focus and the extremities of the diameter of the lens. On this account the increase of the angle of aperture has been a chief aim with practical opticians.

Penetrating power is the degree of distinctness with which the parts of an object lying a little out of focus may be seen. Objectives which have a large angle of aperture, and in consequence great resolving power, are often defective in penetration, their very perfection only permitting accurate vision of what is actually in focus. Hence for general purposes a moderate degree of angular aperture is desirable.

Flatness of field of view is also a necessity for accurate observation. Many inferior microscopes hide their imperfection in this respect by a contracted aperture in the eye-piece, by which, of course, only a part of the rays transmitted by the objective are available.

Object-glasses whose focal length is greater than half an inch are called low powers. Medium powers range from one-half to one-fifth of an inch focal length, and all objectives less than one-fifth are considered high powers.

For definition with low power objectives, the pollen grains of hollyhock, or the tongue of a fly, or a specimen of injected animal tissue, will be a sufficient test. The aperture should be enough to give a bright image, and the definition sufficient for a clear image. A section of wood, or of an echinus spine, will test the flatness of the field.

Medium powers are seldom used with opaque objects unless they are very small, but are most useful with

properly prepared transparent objects. A good half-inch objective should show the transverse markings between the longitudinal ribs on the scales of the *Hipparchia janira*, butterfly (Plate I, Fig. 27), and the one-fourth or one-fifth should exhibit markings like exclamation points on the smaller scales of *Podura plumbea* (Plate I, Fig. 28) or *Lepidocyrtis*.

High power objectives are chiefly used for the most delicate and refined investigations of structure, and are not so suitable for general work. It is with these glasses that angular aperture is so necessary to bring out striæ, and dots, and other delicate structures, under oblique illumination. For these glasses, the best tests are the siliceous envelopes of diatoms, as the *Pleurosigma angulatum*, *Surirella gemma*, *Grammatophora subtilissima;* or the wonderful plates of glass artificially ruled by M. Nobert, and known as Nobert's test.

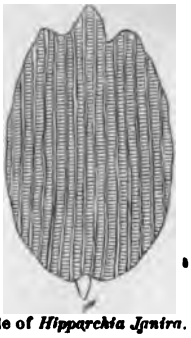
The latter test is a series of lines in bands, the distance between the lines decreasing in each band, until their existence becomes a matter of faith rather than of sight, since no glass has ever revealed the most difficult of them. The test plate has nineteen bands, and their lines are ruled at the following distances: Band 1, $\frac{1}{1000}$th of a Paris line (to an English inch as .088 to 1.000, or as 11 to 125). Band 2, $\frac{1}{1500}$th. Band 3, $\frac{1}{2000}$th. Band 5, $\frac{1}{3000}$th. Band 9, $\frac{1}{5000}$th. Band 13, $\frac{1}{7000}$th. Band 17, $\frac{1}{9000}$th. Band 19, $\frac{1}{10000}$th.

It is said that Hartnack's immersion system No. 10 and oblique light has resolved the lines in the 15th band, in which the distance of lines is about $\frac{1}{9\,1000}$th of an inch.

The surface markings of minute diatoms are also excessively fine. Those of *Pleurosigma formosum* being from 20 to 32 in $\frac{1}{1000}$th of an inch; of *P. hippocampus* and *P. attenuatum* about 40; *P. angulatum* 46 to 52; *Navicula rhomboides* 60 to 111; and *Amphipleura pellucida* 120 to 130. This latter has been variously estimated at 100,000

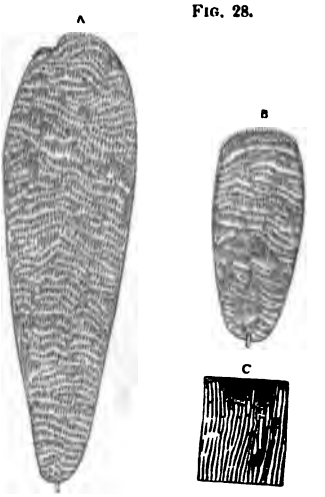
PLATE I.

FIG. 27.



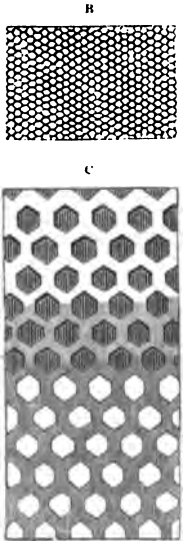
Scale of *Hipparchia Janira*.

FIG. 28.



Scales of *Polura plumbea*:—A, large strongly marked scale; B, small scale more faintly marked; C, portion of an injured scale, showing the nature of the markings.

FIG. 29.

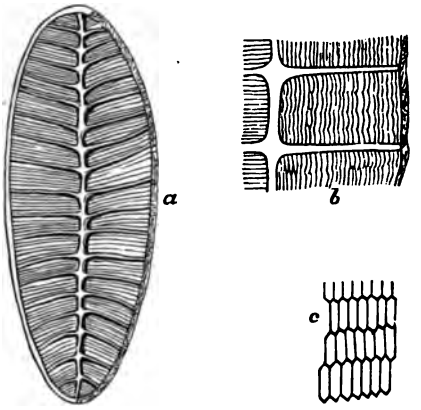


Pleurosigma angulatum:—A, entire frustule, as seen under a power of 500 diam.; B, hexagonal aerolation, as seen under a power of 1300 diam.; C, the same, as seen under a power of 15,000 diam.

to 130,000 in an inch. It has been resolved by Dr. Woodward with the $\frac{1}{18}$th immersion of Powell and Lealand, using oblique sunlight through a solution of ammonio-sulphate of copper.

The longitudinal lines (between the transverse) of the

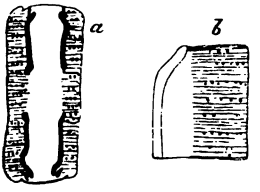
FIG. 30.



Valve of Surirella Gemma.
a. Transverse ridges. *b*. Longitudinal lines. *c*. The same, resolved into areolations.

Surirella gemma are estimated at 30 to 32 in $\frac{1}{100}$th of a millimetre, and the markings on *Grammataphora subtilissima* at 32 to 34 in the same distance.

FIG. 31.



Grammataphora Subtilissima.
a. Valve. *b*. Transverse lines.

J. D. Moller has produced a very excellent test-plate, containing twenty diatoms, with descriptions, according to their value as tests.

The *Pleurosigma angulatum* (Plate I, Fig. 29), with suitable power and illumination, should show distinct hexagonal areolations. The *Surirella gemma* (Fig. 30) shows a series of fine transverse lines across the ridges which run from the edge to the central line. The finest of these ridges are not always readily seen, and the transverse ones are only to be mastered by toil and patience.

The *Grammataphora subtilissima* (Fig. 31) shows transverse lines (or rows of dots) along the edge, and sometimes a double series of oblique lines.

CHAPTER V.

MODERN METHODS OF EXAMINATION.

Microscopy does not limit its researches to optical enlargement, but seeks to comprehend elementary structure, and its methods vary according to the object immediately in view. It may seek merely to discern the form or morphology of the elementary parts or their peculiar functions. It may be concerned with inorganic forms, normal or pathological anatomy, or with physiology. Each department of pursuit will suggest some variation, yet a general plan of operation is possible.

Coarse, and moderately large objects, as a small insect, a piece of vegetable tissue, etc., may be observed by placing it in the forceps, or on the stage of the instrument, under an objective of low power, but ordinarily a considerable degree of preparation is needed in order to acquire a true idea of structure.

Most of the tissues to be examined are in a moist con-

dition, and many require to be dissected or preserved in fluid. This has much to do with the appearance of the object in the microscope. If fibres or cells are imbedded in connective tissue or in fluids, of which the refractive power is the same as their own, they cannot be perceived even with the best glasses, and artificial means must be resorted to that they may become visible. The refractive power of different media causes different appearances. Thus a glass rod lying in water is easily seen, but in Canada balsam, whose refractive power is nearly the same as glass, it is barely seen as a flat band, and in the more highly refractive anise oil it presents the appearance of a cavity in the oil.

During life the cavities and fissures in animal tissues, in consequence of the different refractive power of their contents and the change which takes place soon after death, exhibit a sharpness and softness of outline which is seldom seen in preparations.

There are two methods of microscopic investigation or of preparation preliminary to direct observation: 1. Mechanical, for the separation and isolation of the elementary parts. 2. Chemical, which dissolve the connecting material, or act on it differently than on other elements.

For minute dissection a great variety of instruments have been proposed, but by practiced hands more can be accomplished in shorter time by simple means than with complicated ones. Two or three scalpels, or small anatomical knives, a pair of small scissors, such as is used in operations on the eye, and fine-pointed forceps, will be found useful. But the most serviceable instruments are dissecting-needles, such as the microscopist may make for himself. A common sewing-needle, with the eye end thrust into a cedar stick about three inches long and one-fourth of an inch diameter, will answer the purpose. The point should not project so far as to spring, and if desired, a cutting edge can be given to it by a hone.

The light should be concentrated on the work by means of a bull's-eye condenser, and as far as possible, the dissection should be carried on with the unassisted eye. Very often the work is so fine that a magnifying glass, or simple microscope, fixed to a suitable arm, will be needed. A large Coldington lens, an inch and a half in diameter, such as is used frequently by miners, will be useful. Sometimes it is necessary to resort to the dissecting microscope, which is a simple lens, of greater or less power, arranged with rack and pinion, mirror, etc.

The specimen may be dissected under water, in a glass or porcelain dish, or a trough made of gutta-percha, etc. Dr. Lawson's binocular dissecting microscope (Fig. 32) is

FIG. 32.

Lawson's Binocular Dissecting Microscope.

a most useful form, as both eyes may be used. Loaded corks, with sheet lead fastened to their under surface, may be used to pin the subject on for greater facility in dissection. Rests, or inclined planes of wood, one on each side of the trough, will give steadiness to the hands. Camels'-hair pencils for the removal of dust and extrane-

ous elements, and for spreading out thin and delicate tissues or sections, are indispensable. Pipettes, or glass tubes, one end of which can be covered with the end of the finger, may serve to convey a drop of fluid or a small specimen from a bottle.

Preparation of Loose Textures.—If the formed elements of tissue do not combine in a solid mass, it is only necessary to place a small quantity on a glass slide and cover it with a plate of thin glass. If the elements are too close for clear definition under the microscope, a drop of fluid may be added. The nature of this fluid, however, is not a matter of indifference. Some elements are greatly changed by water, etc., and it becomes important to consider the fluid which is most indifferent. Glycerin and water, one part to nine of water, will serve well for most objects. Animal tissues are often best treated with aqueous humor, serum, or iodized serum. A weak solution of salt, 7.5 grains chloride of sodium to 1000 grains of distilled water, serves for many delicate structures. (See section on *Fluid Media.*)

Preparation by Teasing.—A minute fragment of tissue should be placed in a drop of fluid on a slide, and torn or unravelled by two sharp needles. This is accomplished more easily after maceration, and sometimes it is necessary to macerate in a substance which will dissolve the connecting material. This picking or teasing should be slowly and accurately performed. Beginners often fail of a good preparation by ceasing too soon, as well as by having too large a specimen. The most delicate manipulation is required to isolate nerve-cells and processes.

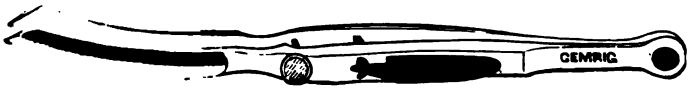
Preparation by Section.—A section of soft substance may be made with a sharp knife or scalpel, or with a pair of scissors curved on the upper side. A section cut with the latter will taper away at the edges so as to afford a view of its structure.

Valentin's double knife (Fig. 33) is used for soft tissues where only a moderate degree of thinness is needed. The knife should be wet, or the section made under water.

Soft substances often require hardening before sections can be made. The most simple and best method is that of freezing, by surrounding the specimen with a freezing mixture, when it may be cut with a cold knife. Small pieces of tissue may be hardened in absolute alcohol, frequently renewed. Chromic acid, in solution of one-fourth to two per cent., is often used for animal tissues, or bichromate of potash of the same strength. A solution of one-fifth to one-tenth per cent. of perosmic acid or of chloride of palladium is also recommended.

Soft tissues often require imbedding in a concentrated solution of gum or of wax, spermaceti, or paraffin tempered with oil. In this case sections may be made readily by means of a section-cutter. For imbedding in wax, etc.,

Fig. 33.



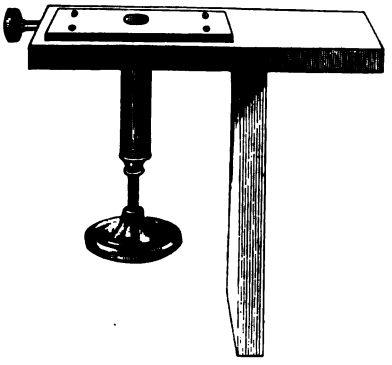
Valentin's Knife.

the specimen must be hardened in alcohol, then treated with oil of cloves or turpentine, and the section should be mounted in Canada balsam or Dammar varnish.

Sections of hard substances, or of those imbedded, are often made by machines invented for the purpose. One of the simplest is (Fig. 34) an upright hollow cylinder, with a kind of piston, pushed upwards by a fine screw. The upper end of the cylinder carrying the specimen terminates in a flat table, along which a sharp knife or flat razor is made to slide. At one side of the tube is a binding screw for holding the specimen steady. A sec-

tion may be cut by such an instrument after inserting the structure desired in a piece of carrot, etc., which may be placed in the tube; or the tube may be filled with wax, etc., and the specimen imbedded. Bones, teeth, shells, corals, minerals, etc., require to be cut with fine saws, or a disk of thin iron on a lapidary's wheel, and filed or ground down to the requisite thinness, then polished with emery, rouge, etc. The green oxide of chromium has been suggested to me as a useful polishing powder for hard substances. For calcareous substances, files and hones will suffice to reduce the thickness, and putty

FIG. 34.



Section-Cutter.

powder or jewellers' rouge for polishing. They should be mounted in Canada balsam.

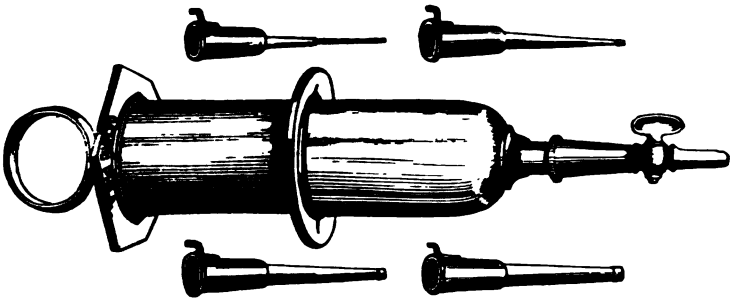
Staining Tissues.—Certain elements, not previously visible, can often be made evident by certain coloring matters, by which some constituents become more quickly or more thoroughly stained than others. The "germinal matter," or "bioplasm" of Dr. Beale, identical with the "protoplasm" or "sarcode" of other observers, may thus be distinguished from the "formed materials" or "tissue ele-

ment," which are the products of its activity. Carmine, anilin, hæmatoxylin, and picric acid, are used for staining by imparting their own color to tissues; while nitrate of silver, chloride of gold, chloride of palladium, and perosmic acid stain, by their chemical action, often under the reducing influence of light. (See *Fluid Media.*)

Injecting Tissues.—Injections of the vessels in animal tissues are resorted to either to exhibit their course or the structure of the vascular walls. For the latter purpose a solution of nitrate of silver is commonly employed, for the former either opaque or transparent coloring matter. (See *Fluid Media.*)

The injecting syringe (Fig. 35) is made of brass or Ger-

FIG. 35.



Injecting Syringe.

man silver. One of the pipes should be inserted into the principal vessel, as the aorta of a small animal, the umbilical vein of a fœtus, or the artery, etc, of an organ, and should be securely fastened by a thread. All other open vessels should be tied. The solution of gelatin, or other matter used, should be strained, so as to be free from foreign particles, and should be forced into the vessels with a gentle, steady pressure on the syringe.

Injections should be made soon after the death of the animal, or else after the rigor mortis has subsided.

Sometimes the syringe is substituted by a self-acting apparatus, consisting of a Wolfe's bottle, containing the fluid, which is pressed upon by a column of air from another source, and driven through a flexible tube to the pipe in the bloodvessel.

The older anatomists used colored plaster or wax to demonstrate the arteries and veins, but modern histology requires finer materials. Isinglass or gelatin, colored, and injected warm, or a solution of colored glycerin, are now resorted to. The former serves for opaque, and the latter for fine, transparent injections.

The art of injecting can only be learned by practice, yet perseverance, in despite of many failures, will insure success.

The liver, kidney, etc., may be injected separately, and it is often desirable to use various colors for the different sets of vessels. After injection thin slices may be cut off and mounted in fluid or balsam.

Preparation in Viscid Media.—Dr. Beale has proposed a method of preparing animal and vegetable tissues for examination with the very highest powers, which has led to valuable results. It consists in using pure glycerin or strong syrup, instead of watery solutions. In this way an amount of pressure may be applied to sections, in order to render them thin enough for examination, which would be destructive to specimens in water, while the preservative action of the media prevents change in the structure. It is necessary to soak the specimen some time, and the strength of the fluid should be gradually increased until the tissue is permeated by the strongest that can be obtained. Dr. Beale has found that minute dissection is much more readily performed in such fluids, and that even very hard textures, as bone and teeth, may be softened by them, especially if acetic acid is added, so as to permit thin sections to be made with a knife. He recommends

vessels to be first injected, as with fine, transparent blue, and the germinal matter to be stained with carmine. A few drops of a solution of chromic acid, or bichromate of potash, so as to impart to the glycerin a pale straw color, serves to harden even the finest nerve-structures. Acetic acid, and other reagents also, are much more satisfactorily used with glycerin than with water. If syrup is used, camphor, carbolic acid, etc , must be employed to prevent the growth of fungi, but pure glycerin is free from this inconvenience.

A great advantage of this mode of investigation consists in the fact that a specimen thus prepared is already mounted, and needs but a proper cement to the glass cover and a finish to the slide, when it is ready for the cabinet.

FLUID MEDIA.

1. Indifferent Fluids.

The vitreous humor, amniotic liquor, serum, etc., which form the usual fluids termed indifferent, always contain what Prof. Graham designated colloid and crystalloid substances. In 1000 parts there are about 4 parts of colloid (albumen) and 7.5 of crystalloid substance (chloride of sodium).

The iodine serum of Schultze consists of the amniotic fluid of the embryo of a ruminant, to which about 6 drops of tincture of iodine to the ounce is added A small piece of camphor will preserve this from decomposition a long time. A substitute for this is composed of 1 ounce of white of egg, 9 ounces of water, 2 scruples chloride of sodium, with the corresponding quantity of tincture of iodine.

2. Chemical Reagents.

The greatest care should be used with these, that the instrument and glasses may be preserved. A small drop, applied by a glass rod drawn out to a point to the edge of the glass cover, will suffice in most cases.

Sulphuric Acid.—Concentrated is used to isolate the cells of horny structures, as hair, nails, etc. Dilute (1 part to 2–3 of water) gives to cellulose, previously dyed with iodine, a blue or purple color, and, when mixed with sugar, a rose-red to nitrogenous substances and bile. 0.1 to 1000 of water, at a temperature of 35–40° C., resolves connective tissue into gelatin and dissolves it, so as to be useful in isolating muscular fibres.

Nitric Acid.—Diluted with 4 or 5 parts water, separates the elementary parts of many vegetable and animal tissues when they are boiled or macerated in it. With chlorate of potash it is still more energetic, but caution is needed in its use.

Muriatic Acid, Strong.—Used for dissolving intercellular substance, as in the tubes of the kidney, etc. Dilute for dissolving calcareous matter.

Chromic acid, ½ to 2 per cent. solution for hardening nerves, brain, etc.

Oxalic acid, to 15 parts water, causes connective tissue to swell and become transparent, while albuminoid elements are hardened. Preserves well delicate substances, as rods of retina, etc.

Acetic acid makes nuclei visible and connective tissue transparent, so as to exhibit muscles, nerves, etc., otherwise invisible.

Iodine (1 grain of iodine, 3 grains iodide of potassium, 1 ounce of water) turns starch blue and cellulose brown.

Caustic potash or soda renders many structures transparent.

Lime-water or baryta-water is used for investigating connective structures, especially tendon, as maceration enables the needle to divide its fibrilla.

Chloride of Sodium.—Solutions of this salt for indifferent media should always have some colloid, as albumen or gum-arabic added (7.5 grains in 1000 grains of water for delicate structures).

Bichromate of potash is used in stronger solution for the same purposes as chromic acid.

Müller's eye-fluid for hardening the retina, and preserving delicate embryos, etc., consists of bichromate of potass., 2 grammes; sulphate of soda, 1 gramme; distilled water, 100 grammes.

Alcohol dissolves resins and many vegetable coloring matters; renders most vegetable preparations more transparent, and albuminous animal tissues more opaque.

Acetic acid and alcohol, 1 part of each to 2 of water, renders connective tissue transparent, and albuminoid tissue prominent. The proportions can be varied.

Alcohol and soda (8–10 drops of strong solution of caustic soda to each ounce) renders many tissues very hard and transparent. Beale recommends it for embryonic structures.

Ether dissolves resins, oils, and fat.

Turpentine renders dried animal sections transparent.

Oil of cloves acts as turpentine.

Solution of chloride of zinc, iodine, and iodide of potassium, is recommended by Schacht as a substitute for iodine and sulphuric acid to color vegetable cells, etc. Zinc is dissolved in hydrochloric acid, and the solution is evaporated to syrupy consistence in contact with metallic zinc. This is saturated with iodide of potassium, iodine added, and the solution diluted with water. Wood cells, after boiling in caustic potash, are stained blue by it.

Boracic acid, used by Prof. Brucke to separate the elements of red blood-corpuscles.

3. Staining Fluids.

Thiersch's Carmine Fluids.

a. Red Fluid.

1.	Carmine,	1 part.	
	Caustic ammonia,	1 "	
	Distilled water,	8 parts.	Filter.
2.	Oxalic acid,	1 part.	
	Distilled water,	22 parts.	

1 part of carmine solution to 8 parts of the acid solution, add 12 parts absolute alcohol. Filter. After staining wash in 80 per cent. alcohol.

b. Lilac Fluid.

	Borax,	4 parts.
	Distilled water,	56 "
Dissolve and add,		
	Carmine,	1 part.

Mix with twice the volume of absolute alcohol and filter.

Beale's Carmine Fluids.

Carmine,	10 grains.
Strong liquor ammonia,	½ drachm.
Glycerin,	2 ounces.
Distilled water,	2 "
Alcohol,	½ ounce.

Dissolve the carmine in the ammonia in a test-tube by aid of heat; boil it and cool and add the other ingredients. Filter.

Acid Carmine Fluid.—Mix ammoniacal solution of carmine with acetic acid in excess and filter. This is said to stain diffusely, but adding glycerin with muriatic acid (1 : 200), concentrates the color in the cell-nucleus.

Anilin (or Magenta) Red Fluid.

Fuchsin (crystal),	1 centigramme.
Absolute alcohol,	20–25 drops.
Distilled water,	15 cubic centim.

Anilin Blue Fluid.—Anilin blue, treated with sulphuric acid and dissolved in water till a deep cobalt color is obtained.

Blue Fluid from Indigo Carmine.

Oxalic acid, ... 1 part.
Distilled water, ... 20–30 parts.
Indigo carmine to saturation.

Logwood Violet Fluid.

1. Hæmatoxylin, ... 20 grains.
   Absolute alcohol, ... ½ ounce.
2. Solution of 2 grains of alum to 1 ounce of water.

A few drops of the first solution to a little of the second in a watch-glass, etc.

Picro-Carmine Fluid.—Filter a saturated solution of picric acid, and add, drop by drop, strong ammoniacal solution of carmine till neutralized.

Nitrate of Silver Fluid.—Fresh membranous tissues, exposed to 0.5 to 0.2 per cent. solution of nitrate of silver, washed and exposed to light, often show a mosaic of epithelium, etc.

Osmic Acid.—$\frac{1}{10}$th to 1 per cent. solution stains the medulla of nerves, etc., black.

Chloride of Gold.—The solution should be similar to that of nitrate of silver. Exposure to light stains the nerves, etc., a violet or red color.

Prussian Blue.—After immersing a tissue in 0.5 to 1 per cent. solution of a protosalt of iron, dip it in a 1 per cent. solution of ferrocyanide of potassium.

Other Staining Fluids.—Marked effects are often produced by the use of the violet, blue, and other inks in the market. Thus I succeeded in some demonstrations of nerve plexuses in muscle better than in any other way. I suspect the particular ink employed contained a large per cent. of soluble Prussian blue.

4. Injecting Fluids.

For opaque injection several plans have been devised. Resinous and gelatinous substances, variously colored, are

most usual. Lieberkuhn used tallow, varnish, and turpentine, colored with cinnabar; and Hyrtl, whose preparations have been much admired, follows a similar plan. He evaporates pure copal or mastic varnish to the consistence of syrup, and grinds one-eighth as much cinnabar and a little wax with it on a slab. For fine injections this is diluted with ether.

For a bright red, the cinnabar may be mixed with a little carmine

For a yellow color, the chromate of lead, prepared by mixing solutions of acetate of lead (36 parts to 2 ounces of water), and red chromate of potash (15 parts).

White may be made with zinc-white or carbonate of lead—4½ ounces of acetate of lead in 16 ounces of water, mixed with 3½ ounces carbonate of soda in 16 ounces.

For gelatinous injections the coloring matter is combined with jelly, prepared by soaking fine gelatin in cold water for several hours, then dissolving in a water-bath and filtering through flannel.

By injecting gelatinous fluid solutions of various salts, the coloring matter may be left in the vessels by double decomposition.

A red precipitate, with iodide of potassium and bichloride of mercury.

A blue, by ferrocyanide of potassium and peroxide of iron, etc.

Dr. Goadby's formula for a yellow color is:

Saturated solution of bichromate of potassium,	8 ounces.
Water,	8 "
Gelatin,	2 "
Saturated solution of acetate of lead,	8 ounces.
Water,	8 "
Gelatin,	2 "

For gelatinous injections, both the fluid and the subject should be as warm as may consist with convenience. Camphor also should be added to prevent mould.

For transparent injections, gelatin may be used combined with colored solutions, or still better, glycerin, which may be used cold.

Thiersch's Blue.—Half an ounce of warm concentrated solution (2 : 1) of fine gelatin is mixed with 6 cubic centimetres of a saturated solution of sulphate of iron. In another vessel, 1 ounce of the gelatin solution is mixed with 12 cubic centimetres of saturated solution of ferrocyanide of potassium, to which 12 cubic centimetres of saturated solution of oxalic acid is added. When cold, add the gelatinous solution of sulphate of iron drop by drop, with constant stirring, to the other. Warm it, still stirring, and filter through flannel.

Gerlach's Carmine.—Dissolve 5 grammes (77 grains) of fine carmine in 4 grammes (70 grains) of water and ½ gramme (8 drops) of liquor ammonia. Let it stand several days (not airtight), and mix with a solution of 6 grammes of fine gelatin to 8 grammes of water, to which a few drops of acetic acid are added.

Thiersch's Yellow.—Prepare a solution of chromate of potash (1 : 11), and a second solution of nitrate of lead, of same strength. To 1 part of the first add 4 parts of solution of gelatin (about 20 cubic centimetres to 80), and to 2 parts of the second add 4 parts of gelatin (40 cubic centimetres to 80). Mix slowly and carefully, heat on a water-bath, and filter through flannel.

Equal parts of Thiersch's blue and yellow carefully mixed and filtered make a good green.

COLD TRANSPARENT INJECTIONS.

Beale's Blue.

Glycerin,	1 ounce.
Alcohol,	1 "
Ferrocyanide of potassium,	12 grains.
Tincture of perchloride of iron,	1 drachm.
Water,	4 ounces.

Dissolve the ferrocyanide in 1 ounce of water and glycerin, and the muriated tincture of iron in another ounce. Add the latter very gradually to the other, shaking often; then gradually add the alcohol and water.

Beale's Finest Blue.

Price's glycerin,	2 ounces.
Tincture of perchloride of iron,	10 drops.
Ferrocyanide of potassium,	8 grains.
Strong hydrochloric acid,	8 drops.
Water,	1 ounce.

Mix the tincture of iron with 1 ounce glycerin and the ferrocyanide, after dissolving in a little water, with the other ounce. Add the iron to the other solution gradually, shaking well. Lastly, add the water and hydrochloric acid. Sometimes about 2 drachms of alcohol are added.

Müller's Blue.—This is made by precipitation of soluble Prussian blue from a concentrated solution by means of 90 per cent. alcohol.

Beale's Carmine.—Mix 5 grains of carmine with a few drops of water, and when well incorporated, add 5 or 6 drops of liquor ammonia. To this add ½ ounce of glycerin, and shake well. Another ½ ounce of glycerin containing 8 or 10 drops of acetic or hydrochloric acid is gradually added. It is then diluted with ½ ounce of glycerin, 2 drachms of alcohol, and 6 drachms of water.

Nitrate of Silver Injection.—For demonstrating the structure of the bloodvessels, the animal is bled, and a solution of 0.25 to 1 per cent. of nitrate of silver, or a mixture of gelatin with such a solution, is used.

5. Preservative Fluids.

Canada Balsam.—This is perhaps the most common medium used. When an object is not very transparent, and drying will not injure it, balsam will do very well,

but it is not adapted to moist preparations. Colonel Woodward, of Washington, uses a solution of dried or evaporated Canada balsam in chloroform or benzole.

Dammar Varnish.—Dr. Klein and other German histologists prefers this to Canada balsam. Dissolve ½ to 1 ounce of gum Dammar in 1 ounce of turpentine; also ½ to 1 ounce of mastic in 2 ounces of chloroform. Mix and filter.

Glycerin.—This fluid is universally useful to the microscopist. (See *Preparation in Viscid Media*, page 65.) Vegetable and animal substances may be preserved in glycerin, but if it is diluted, camphor or creasote must be added to prevent confervoid growths. It is said, however, to dissolve carbonate of lime.

Gelatin and Glycerin.—Soak gelatin in cold water till soft, then melt in warm water, and add an equal quantity of glycerin.

Gum and Glycerin.—Dissolve 1½ grains of arsenious acid in 1 ounce of water, then 1 ounce of pure gum arabic (without heat), and add 1 ounce of glycerin.

Deane's Compound.—Soak 1 ounce of gelatin in 5 ounces of water till soft; add 5 ounces of honey at a boiling heat. Boil the mixture, and when cool, add 6 drops of creasote in ½ ounce of alcohol; filter through flannel. To be used warm.

Carbolic Acid.—1 : 100 of water is a good preservative.

Thwaite's Fluid.—To 16 parts of distilled water, add 1 part of rectified spirit and a few drops of creasote; stir in a little prepared chalk, and filter. Mix an equal measure of camphor-water, and strain before using. For preservation of algæ.

Solution of Naphtha and Creasote.—Mix 3 drachms of creasote with 6 ounces of wood naphtha; make a thick, smooth paste with prepared chalk, and add gradually, rubbing in a mortar, 64 ounces of water. Add a few lumps of camphor, and let it stand several weeks before

pouring off or filtering the clear fluid. Dr. Beale recommends this highly for the preservation of dissections of nerves and morbid specimens.

Ralf's Fluid.—As a substitute for Thwaite's fluid in the preservation of algæ. 1 grain of alum and 1 of bay salt to 1 ounce of distilled water.

Goadby's Solution.—Bay salt, 4 ounces; alum, 2 ounces; corrosive sublimate, 4 grains; boiling water, 4 pints. This is the strength most generally useful, although it may be made stronger or more dilute. It is a useful fluid. If the specimen contain carbonate of lime, the alum must be left out, and the quantity of salt may be quadrupled.

Dr. Beale discards all solutions containing salts for microscopic purposes, as they render the textures opaque and granular.

Soluble Glass, or a solution of silicate of soda or potash, or of both, has been proposed, but it is apt to render specimens opaque.

Chloride of Calcium in saturated aqueous solution has been much recommended, especially by botanists.

Acetate of Potash, a nearly saturated solution, is useful for vegetable preparations and for specimens of animal tissue which have been stained with osmic acid. The latter do not bear glycerin.

Pacinian Fluid.—This is variously modified, but may consist of corrosive sublimate, 1 part; chloride of sodium, 2 parts; glycerin, 13 parts; distilled water, 113 parts. Sometimes acetic acid is substituted for chloride of sodium.

6. Cements.

Gold Size is recommended by Dr. Carpenter as most generally useful for thin covers. It is made by boiling 25 parts of linseed oil for three hours with 1 part of red lead and ⅓ of as much umber. The fluid part is then mixed with yellow ochre and white lead in equal parts,

so as to thicken it, the whole boiled again, and the fluid poured off for use.

Bell's Cement is said to be best for glycerin specimens. It appears to be shellac dissolved in strong alcohol.

Brunswick Black is asphaltum dissolved in turpentine. A little india-rubber dissolved in mineral naphtha is sometimes added.

Canada Balsam in chloroform or Dammar varnish (page 74) is often used as a cement.

Marine Glue.—This is most useful in building glass cells, etc. It consists of equal parts of shellac and india-rubber dissolved in mineral naphtha by means of heat.

Electrical Cement is made by melting together 5 parts of rosin, 1 of beeswax, and 1 of red ochre. 2 parts of Canada balsam added make it more adhesive to glass.

White, hard Varnish, or gum sandarac, dissolved in alcohol and mixed with turpentine varnish, is sometimes colored by lampblack, sealing-wax, etc.

White Zinc Cement.—Oxide of zinc rubbed up with equal parts of oil of turpentine and 8 parts of solution of gum Dammar in turpentine of a syrupy consistence, or Canada balsam, chloroform, and oxide of zinc.

CHAPTER VI.

MOUNTING AND PRESERVING OBJECTS FOR THE MICROSCOPE.

For the permanent preservation of specimens, various means are employed, according to the nature of the object and the particular line of investigation desired. Few, if any, objects show all their peculiarities of structure or adaptation to function, and for scientific work it is often

necessary to have the same structure prepared in different ways.

Opaque Objects have sometimes been attached by thick gum to small disks of paper, etc., or to the bottom and sides of small pill-boxes, or in cavities in slides of bone or wood, but they are better preserved on glass slides, as hereafter described.

The most convenient form of slide for microscopic purposes is made of flattened crown or flint glass, cut into slips of three inches by one inch, and ground at the edges. Some preparations are mounted on smaller slips, but they are less convenient than the above, which is regarded as the standard size.

On such slides objects are fixed, and covered by a square or round piece of thin glass, varying from $\frac{1}{20}$th to $\frac{1}{250}$th of an inch in thickness. Both slides and thin glass can be procured at opticians' stores. Laminæ of mica or talc are sometimes used for lack of better material, but are too soft. For object-glasses of the shortest focal length, however, it is necessary at times to resort to this sort of covering.

Great care should be taken to have both slide and cover clean. With thin glass this is difficult, owing to its brittleness. Practice will teach much, but for the thinnest glass two flat pieces of wood covered with chamois leather, between which the cover may lie flat as it is rubbed, will be serviceable.

Very thin specimens may be mounted in balsam, glycerin, etc., covered with the thin glass cover, and then secured by a careful application of cement to the edges of the cover. If, however, the pressure of the thin glass be objectionable, or the object be of moderate thickness, some sort of cell should be constructed on the slide.

The thinnest cells are made with cement, as gold size, Brunswick black, etc., painted on with a camel's-hair pencil. For preparing these with elegance, Shadbolt's *turn-*

table has been contrived (Fig. 36). The slide is placed between the springs, and while rotated, a ring of varnish of suitable breadth is made on the glass.

A piece of thin glass (or even of thick glass) may be perforated and cemented to the slide with marine glue by

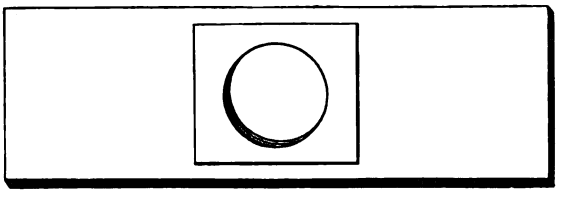
FIG. 36.

Shadbolt's Turntable for making Cement-Cells.

the aid of heat; or vulcanite, lead, tin, gutta percha, etc., may be made into a cell in a similar way as seen in Fig. 37.

The perforation of thin glass may be easily performed by cementing it over a hole in a brass plate, etc., with marine glue, and punching it through with the end of a

FIG. 37.



Cell of Glass, Vulcanite, etc.

file. The edges may then be filed to the size of the hole, and the glass removed by heating the brass. Thicker glass may be bored with a file by moistening it with turpentine.

Dry objects, especially if they are transparent, as diatoms, thin sections of bone, crystals, etc., may be attached to the slide with Canada balsam, etc., covered with thin

glass, which should be cemented at the edges, and gummed over all a strip of colored or lithographed paper, in which an aperture has been made with a punch.

Mounting in Balsam or Dammar Varnish is suitable for a very large proportion of objects. It increases the transparency of many structures, filling up interstices and cavities, and giving them a smooth, beautiful appearance. Very delicate tissues, as fine nerves, etc., are rendered invisible by it, and require other fluids, as glycerin.

Before mounting in balsam, the object should be thoroughly dry, otherwise a milky appearance will result. It should then be placed in oil of cloves or of turpentine to remove greasiness and increase the transparency. A clean slide, warmed over a spirit-lamp or on a hot plate, should then have a little balsam placed on its centre, and the object carefully lifted from the turpentine is put into the balsam and covered with another drop. The slide should then be gently warmed, and any air-bubbles pricked with a needle-point or drawn aside. The thin glass cover should be warmed and put on gently, in such a way as to lean first on one edge and fall gradually to a horizontal position. The slide may be warmed again, and the superfluous balsam pressed from under the cover by the pressure of a clean point upon it.

If the object is full of large air-spaces and is not likely to be injured by heat, the air may be expelled by gently boiling it in the balsam on the slide. If the object be one which will curl up, or is otherwise injured by heat, the air-pump must be resorted to. A cheap substitute for the air-pump may be made by fitting a piston into a tolerably wide glass tube closed at one end. The piston should have a valve opening outwards. The preparation in balsam may be placed at the bottom of the tube, and a few strokes of the piston will exhaust the air.

To fill a deep cell with Canada balsam, it may be well to fill it first with turpentine and place the specimen in

it. Then pour in the balsam at one end, the slide being inclined so that the turpentine may run out at the other. Lay the cover on one edge of the cell and gradually lower it till it lies flat. In this way air may be excluded.

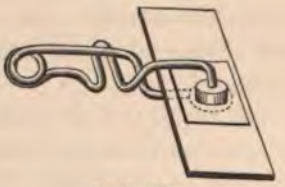
The solution of balsam in chloroform needs no heat, and has little liability of air-bubbles.

The excess of balsam round the edge of the glass cover may be removed with a knife and cleaned with turpentine or benzine, etc.

For animal tissues, the oil of cloves is sometimes used instead of turpentine to increase the transparency, and a wet preparation, as a stained or injected specimen, may be mounted in balsam or Dammar by first placing it in absolute alcohol to extract the water, then transferring to oil of cloves or turpentine, and lastly, to the balsam. In a reverse order, a specimen from balsam may be cleaned and mounted in fluid.

Mounting in Fluid is necessary for the preservation of the most delicate tissues and such as may be injured by

FIG. 38.



Spring Clip.

drying. Glycerin is perhaps the most generally useful fluid. (See *Preservative Fluids*, page 73.)

For mounting in fluid, it is safer to have a thin cell of varnish prepared first than to risk the running in of the cement under the cover, as will be likely to occur otherwise.

The air-pump is sometimes needed in mounting in fluid to get rid of air-bubbles. A spring clip (Fig. 38) is also

a useful instrument for making moderate pressure on the glass cover until the cement on its edge is dry. A dropping-tube with a bulbous funnel, covered with thin india-rubber, for taking up and dropping small quantities of fluid, will also be of service.

Superfluous fluid may be removed from the edge of the cover by a piece of blotting-paper, care being used not to draw away the fluid beneath the cover.

As soon as objects are mounted, the slides should be labelled before cementing is finished, otherwise time will be lost in searching for a particular object among others, or the name may be forgotten.

Boxes of wood or of pasteboard, with grooved racks at the sides, are occasionally used for preserving a collection of specimens. It is better, however, to have a cabinet with drawers or trays so that the specimens may lie flat, with their ends towards the front of the drawer. A piece of porcelain on the end of the drawer is convenient for the name of the class of objects contained, to be written on with lead-pencil.

Collecting Objects.—The methods pursued by naturalists generally will suffice for a large proportion of the objects which are matters of microscopic inquiry, but there are others which, from their minuteness, require special search. Many fresh-water species of microscopic organisms inhabit pools, ditches, and streams. Some attach themselves to the stems and leaves of aquatic plants, or to floating and decaying sticks, etc. Others live in the muddy sediment at the bottom of the water. A *pond stick* has been contrived for the collection of such organisms, consisting of two lengths, sliding one within the other, so that it may be used as a walking-cane. In a screw socket at one end may be placed a curved knife for cutting portions of plants which contain microscopic parasites; or a screw collar for carrying a screw-topped bottle, which serves to bring up a sample of liquid; or it may have a ring for a muslin net.

The net should be confined by an india-rubber band in a groove, so as to be slipped off readily and emptied into a bottle. The collector should have enough bottles to keep organisms from each locality separate, and when animalcules are secured enough, air should be left to insure their safety.

Marine organisms may be obtained in a similar way if they inhabit the neighborhood of the shore, but others can only be secured by means of the dredge or tow-net. The latter may be of fine muslin sewn to a wire ring of twelve inches diameter. It may be fastened with strings to the stern of a boat, or held by a stick so as to project from the side. For the more delicate organisms, the boat should be rowed slowly, so that the net may move gently through the water. Firmer structures may be obtained by attaching a wide-mouthed bottle to the end of a net made conical, and double, so that the inner cone may act as a valve. The bottle may be kept from sinking by a piece of cork. Such a net may be fixed to the stern of a vessel, and drawn up from time to time for examination.

Minute organisms may be examined on the spot by fishing them out of the bottle with a pipette, or small glass tube, and placing them on a slide. A Coddington or other pocket lens will suffice to show which are desirable for preservation.

Many of the lower animals and plants may be kept alive in glass jars for some time. Frogs, etc., may be kept under wire covers with a large piece of moist sponge.

Aquaria of various sorts may be procured and stocked at small expense, and will afford a constant source of instruction. For fresh-water aquaria the bottom of the jar, etc., should be covered with rich black earth, made into a paste, and this should be surmounted with a layer of fine washed sand. Roots of *Valisneria*, *Anacharis*, or *Chara* may then be planted in the earth and the vessel filled with water. As soon as the water is clear, put a

few fresh-water molluscs in to keep down the growth of confervæ, especially such as feed on decayed vegetable matter, as *Planorbis carinatus*, *Paludina vivipara*, or *Amphibia glutinosa*. When bubbles of oxygen gas appear, fish, water insects, etc., may be introduced.

Marine aquaria require more skill than those for fresh water, but for temporary purposes, the plan described by Mr. Highley, in Dr. Beale's *How to Work with the Microscope*, is excellent. He fills a number of German beaker glasses with fresh sea-water, and places them in a sunny window. He then drops in each one or two limpet shells from which the animals have been removed, and upon which small plants of *Enteromorpha* and *Ulva* are growing. In a short time the sides of the jars next the light become coated with spores. He keeps the other sides clean with a piece of wood or sponge, so as to observe the small marine animals which may now be placed in the beakers. In this way a collection will keep healthy for months. After the sides are covered with spores, the sea-weeds may be removed, and the jars placed on a table at such a distance from the window that the light impinges only on the coated half, taking care that there is sufficient light to stimulate the spores to throw off bubbles of oxygen daily.

Prawns, fish, actiniæ, etc., may be fed on shreds of beef which has been pounded and dried, and then macerated in sea-water for a few minutes. All dead animals, slime, or effete matter should be removed by wooden forceps, etc., as soon as noticed.

CHAPTER VII.

THE MICROSCOPE IN MINERALOGY AND GEOLOGY.

Microscopic examination of minute fossil organisms, as Diatoms, Foraminifera, spicules of sponge, etc., has long been a subject of interest. Latterly, however, the microscope has been found to be essential to the study of physical geology and petrology. How many crude and verbose theories respecting cosmogony will disappear by this means of investigation time must reveal, but the animal nature of the *Eozoon Canadense* found in the Serpentine Limestone of the Laurentian formation of Canada, parallel with the Fundamental Gneiss of Europe, and the discovery by Mr. Sorby* of minute cavities filled with fluid in quartz and volcanic rocks, are indications that speculations based upon a merely external or even chemical examination of rock structures are immature and inadequate.

The systematic study of microscopic mineralogy and geology will require a large outlay of time and patience, and the field is one which is scarcely trodden. The plan of this work will only permit a brief outline, sufficient to aid a beginner, and indicating the value and the methods of minute investigation.

Preparation of Specimens.—Examination of the outer surface of a mineral specimen, viewed as an opaque body with a low power and by condensed light, is sometimes useful. The metals and their alloys, with most of their combinations with sulphur, etc , admit of no other method. Occasionally. as in iron and steel, the microscopic structure is best seen by polishing the surface, and then allowing the action of very dilute nitric acid. Mr. Forbes† states

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* See Beale's How to Work with the Microscope.

† The Microscope in Geology, Popular Science Review, No. 25.

that many vitreous specimens (quite transparent) show no trace of structure until the surface has been carefully acted on by hydrofluoric acid.

It is generally necessary to have the specimens flat and smooth, and thin enough to transmit light. Sometimes fragments may be thin enough to show structure when mounted in balsam, as in the case of quartz, obsidian, pitchstone, etc., but usually thin sections must be ground and polished.

Chip off a fragment of the rock as flat and thin as possible, or cut with a lapidary's wheel, or a toothless saw of sheet-iron with emery. Grind down the specimen on an iron or pewter plate in a lathe until perfectly flat. Then grind with finer emery on a slab of fine-grained marble or slate, and finish with water on a fine hone, avoiding all polishing powders or oil. When perfectly smooth, cement the specimen on a square of glass with Canada balsam, and grind the other side until as thin as necessary, finish as before, remove it from the glass, and mount on a glass slide in balsam.

In this way, most silicates, chlorides, fluorides, carbonates, sulphates, borates, many oxides, sulphides, etc., may be prepared for examination by transmitted light. Very soft rocks may be soaked in turpentine, then in soft balsam, and afterwards heated until quite hard. The deep scratches on hard minerals, like quartz, left by the use of coarse emery, may be removed by using fine emery paper held flat on a piece of plate glass, and finally polished with rouge on parchment. Perhaps oxide of chromium from its hardness will be found the best polishing material. Crystals of soluble salts may be ground on emery paper and polished with rouge. Sometimes much may be learned by acting on one side only of a specimen with dilute acid.

Examination of Specimens.—The object of microscopic examination of minerals is to determine not only the nature of the material of which they are composed, but also, and

chiefly, their structure, whether homogeneous, derived from the débris of previous rocks, or from the agency of the organic world. Ordinary mineralogical characteristics, as to hardness, specific gravity, color, lustre, form, cleavage, and fusibility, and above all, chemical composition, may suffice to show the material, but the microscope will give valuable assistance to this end, and is essential to a knowledge of structure.

Crystalline Forms.—The laws of crystallography teach that each chemical combination corresponds to a distinct relation of all the angles which can possibly arise from the primary form, so that the angular inclination of the facets of a crystal is a question of importance. This can be ascertained by a microscope having a revolving stage, properly graduated, or by the use of a *goniometer*, which is a thread stretched across the focus of the eye-lens, and attached to a movable graduated circle and vernier. The eye-piece attached to the polariscope of Hartnack is thus arranged, so as to act also as a goniometer.

Crystals are assumed to possess certain axes, and the form is determined by the relation of the plane surface to these axes. Although the forms of crystals are almost infinitely varied, they may be classified into seven crystallographic systems.

1. *The Regular Cubic or Monometric System* (Fig. 39) — These crystals are symmetrical, about three rectangular axes. The simplest forms are the cube and octahedron. Examples, diamond, most metals, chloride of sodium, fluor spar, alum.

2. *The Quadratic or Dimetric System* (Fig. 40).—Crystals symmetrical, about three rectangular axes, but only two axes of equal length. Examples, sulphate of nickel, tungstate of lead, and double chloride of potassium and copper.

3. *Hexagonal or Rhombohedral System* (Fig. 41).—Crystals with four axes; three equal in length, in one plane,

FIG. 39.

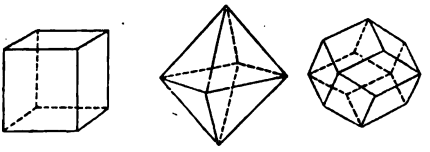
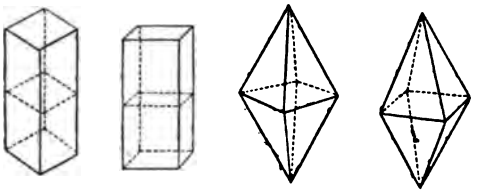
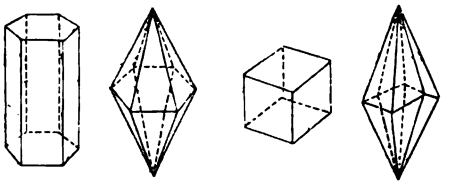


FIG. 40.



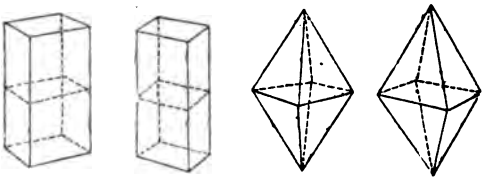
Principal or Vertical Axes. Secondary or Lateral Axes.

FIG. 41.



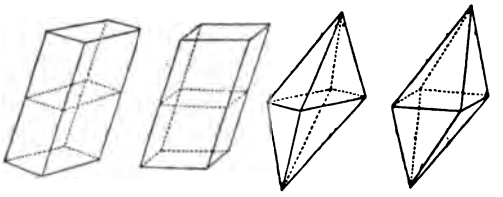
Principal Axes. Secondary Axes.

FIG. 42.



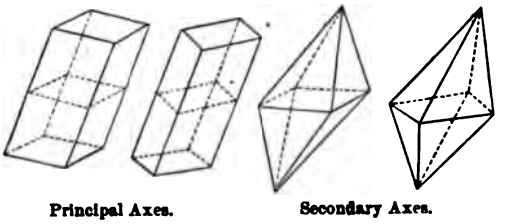
Principal Axes. Secondary Axes.

FIG. 43.



Principal Axes. Secondary Axes.

FIG. 44.



Principal Axes. Secondary Axes.

and inclined 60° to each other, and a principal axis at right angles to the plane of the others. Examples, quartz, beryl, and calc-spar.

4. *Rhombic or Trimetric System* (Fig. 42).—Three rectangular axes, all of different lengths. Examples, sulphate of potassium, nitrate of potassium, sulphate of barium, and sulphate of magnesium.

5. *Oblique Prismatic or Monoclinic* (Fig. 43).—Two axes obliquely inclined, and a third at right angles to the plane of these two; all three being unequal. Examples, ferrous sulphate, sugar, gypsum, and tartaric acid.

6. *Diclinic System.*—Two axes at right angles, and a third oblique to the plane of these; the primary form being a symmetrical eight sided pyramid.

7. *Doubly Oblique Prismatic or Triclinic* (Fig. 44).—Three axes all inclined obliquely and of equal length. Example, sulphate of copper.

Crystalline structure being inherent in the nature of the mineral, becomes perceptible by the manner of division. A slight blow on a piece of calc-spar will separate it into small rhombohedrons or parallelopipeds, or produce internal fissures along the planes of cleavage, which will suffice to determine their angles.

Crystals are often found in groups, with various modes of arrangement. Cubes are sometimes aggregated so as to form octahedra, and prismatic crystals are often united together at one extremity. But the most singular groups are those called hemitropes, because they resemble a crystal cut in two, with one part turned half round and reunited to the other.

In all the numerous forms, however, we find in the same species the same angles or inclination of planes, although the unequal size of the faces may lead to great apparent irregularity, as in distorted crystals of quartz, where one face of the pyramid is enlarged at the expense of the rest.

An apparent distortion may also be produced by an oblique section.

The following examples may be of service, as showing the value of angular measurement in minerals:

Quartz. Rhombohedral system. Inclination of two adjoining faces 94° 15′.

Felspar. Monoclinic. Cleavage planes at right angles.

Albite or soda felspar. Triclinic. Angle 93° 36′.

Mica. Oblique prisms.

Magnesian mica. Right, rhombic, or hexagonal prisms.

Garnet. Dodecahedrons or trapezohedrons.

Idocrase. Square prisms.

Epidote. Oblique prisms.

Scapolite. Square and octagonal prisms.

Andalusite. Prisms of 90° 44′.

Staurotide. Rhombic prisms of 129° 20′.

Tourmaline. Three, six, nine, or twelve-sided prisms.

Topaz. Rhombic prisms of 124° 19′.

Beryl. Six-sided prisms.

Hornblende. Monoclinic. 124° 30′.

Augite or pyroxene. Monoclinic. 87° 5′.

Calcite or carbonate of lime. Forms various, but 105° 5′ between the cleavage faces.

Magnesite. Angle 107° 29′.

Dolomite. 106° 15′.

Gypsum. Monoclinic.

Crystals within Crystals.—Many specimens which appear perfectly homogeneous to the naked eye are shown by the microscope to be very complex. The minerals of erupted lavas are often full of minute crystals, leading to very anomalous results of chemical analysis. Some care is needed at times to distinguish such included minerals from cavities filled with fluid. The use of polarized light will sometimes determine this point.

Cavities in Crystals.—Mr. Sorby has shown that the various cavities in minerals containing air, water, glass,

or stone will often indicate under what conditions the rock was formed. Thus crystals with water cavities were formed from solution; those with stone or glass cavities from igneous fusion; those with both kinds by the combined influence of highly heated water and melted rock under great pressure; while those that contain no cavities were formed very slowly, or from the fusion of homogeneous substance.

Use of Polarized Light.—Mr. Sorby states that the action of crystals on polarized light is due to their double refraction, which depolarizes the polarized beam, and gives rise to colors by interference if the crystal be not too thick in proportion to the intensity of its power of double refraction. This varies much, according to the position in which the crystal is cut, yet we may form a general opinion, since it is the intensity and not the character of the depolarized light which varies according to the position of the crystal. There are two axes at right angles to each other, and when either of them is parallel to the plane of polarization, the crystal has no depolarizing action, and if the polarizing and analyzing prisms are crossed, it looks black. On rotating the crystal or the plane of polarization, the intensity of depolarizing action increases until the axes are at 45°, and then diminishes till the other axis is in the plane. If, therefore, this takes place uniformly over a specimen, we know that it has one simple crystalline structure, but if it breaks up into detached parts, we know it is made up of a number of separate crystalline portions.

The definite order that may occur in the arrangement of a number of crystals may indicate important differences. Some round bodies, for example, like oolitic grains, have been formed by crystals radiating from a common nucleus; whilst others, as in meteorites, have the structure of round bodies which crystallized afterwards.

Sir D. Brewster discovered that many crystals have

two axes of double refraction, or rather axes around which double refraction occurs. Thus nitre crystallizes in six-sided prisms, with angles of about 120°. It has two axes of double refraction inclined about 2½° to the axes of the prism, and 5° to each other, so that a piece cut from such a crystal perpendicular to the axes, shows a double system of rings when a ray of polarized light is transmitted. When the line connecting the axes is inclined 45° to the plane of polarization, a cross is seen, which gradually assumes the form of two hyperbolic curves on rotating the specimen. If the analyzer be revolved, the black cross will be replaced by white, the red rings by green, the yellow by indigo, etc. These rings have the same colors as thin plates, or a system of rings round one axis. Mica has two sets of rings, with the angle between the axes of 60° to 75°. Magnesian mica gives an angle of 5° to 20°.

Determination of the Origin of Rock Specimens.—Mr. Forbes has shown that the primary or eruptive rocks, consisting chiefly of crystallized silicates, with small quantities of other minerals, are developed as more or less perfect crystals at all angles to one another, indicating the fluid state of the mass at some previous time. The secondary or sedimentary rocks consist of rocks formed by the immediate products of the breaking up of eruptive rocks, or are built of the débris of previous eruptive or sedimentary rocks, or composed of extracts from aqueous solution by crystallization, precipitation, or the action of organic life. The accompanying figures, selected from Mr. Forbes's article in the *Popular Science Review*, well illustrate this method of investigation. Plate II, Fig. 45, is a section of lava from Vesuvius, magnified twelve diameters, showing crystals of augite in a hard gray rock. Plate II, Fig. 46, is a volcanic rock from Tahiti, consisting of felspar, with olivine and magnetic oxide of iron, and numerous crystals of a pyroxenic mineral. Plate II, Fig. 47, is pitchstone from a dyke in new

seventy-five diameters. Exter-
green, bottle-glass, but shows in
crystallization of a green
colorless felspar base. Plate II,
diorite from Chili, consisting of
and crystals of iron pyrites, mag-
Plate II, Fig. 48, is a section of
with crystals of orthoclase, hexag-
and colorless quartz, which
contain fluid cavities, magnified
Plate II, Fig. 50, a volcanic rock
dark crystals of augite,
and a little magnetic
diameters. Plate II, Fig.
at right angles to the
is not due to crystalline
magnified two hundred
is an oolitic specimen from
rock by D'Orbigny, but
to be a mere aggregation of
crystalline character of eruptive

Rocks and strata derived
may be arranged in four groups:
of which limestones have been
shells, crinoids, etc. 2. The
contributed to the silica, and may
to the microscopic shields of dia-
fossil sponges. 3. The phosphatic,
Fossil excrements are called
those of birds in large accumulations,
or those which have afforded

the structure of coal, it is necessary to have
From its friability, this is a process
The *Micrographic Dictionary* recom-

PLATE II.

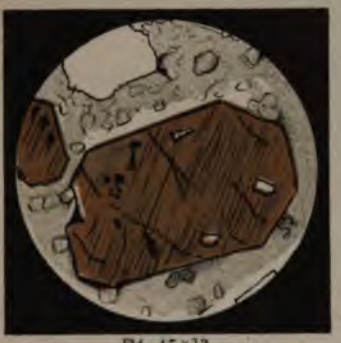


Fig. 45 × 12

Fig. 46 × 12

Fig. 47 × 75

Fig. 48 × 30

Fig. 49 × 25

Fig. 50 × 6

Fig. 51 × 200

Fig. 52 × 30

mends the maceration of the coal for about a week in a solution of carbonate of potassium, when thin slices may be cut with a razor. These should be gently heated in nitric acid, and when they turn yellow, washed in cold water and mounted in glycerin, as spirit and balsam render them opaque. Sometimes, as in anthracite, casts of vegetable fibres may be obtained in the ash after burning and mounted in balsam.

The lignites of the tertiary period show a vegetable structure similar to the woods of the present period, but the older coal of the palæozoic series is a mass of decomposed vegetable matter chiefly derived from the decay of coniferous wood, analogous to the araucariæ, as is seen from the peculiar arrangement of the glandular dots on the woody fibres. Traces of ferns, sigillariæ, calamites, etc., such as are preserved in the shales and sandstones of the coal period, are also met with, but their structure has not been preserved.

Professor Heer, of Zurich, has described and classified several hundred species of fossil plants from the miocene beds of Switzerland by the outlines, nervation, and microscopic structure of the leaves and character of sections of the wood. Several hundred kinds of insects also have been found in the same strata. It is remarkable that a great part of this fossil flora is such as is now common to America, as evergreen oaks, maples, poplars, ternate-leaved pines, and the representatives of the gigantic sequoiæ of California.

The researches of palæontologists have brought to light nearly two thousand species of fossil plants, of which about one-half belong to the carboniferous and one-fourth to the tertiary formations.

The rapid multiplication of the minute microscopic organisms called *diatoms*, is such that Professor Ehrenberg affirms it to have an important influence in blocking up harbors and diminishing the depth of channels. These

organisms, now generally regarded as plants, are exceedingly small, and are usually covered by loricæ or shields of pure silica, beautifully marked, as if engraved. These loricæ or shells having accumulated in great quantities, have given rise to very extensive siliceous strata. Thus the "infusorial earth" of Virginia, on which Richmond and Petersburg are built, is such a deposit eighteen feet in thickness. The polishing material called Tripoli, and

FIG. 53.

Fossil Diatomaceæ, etc., from Mourne Mountain, Ireland: *a, a, a*, Gaillonella (Meloseira) procera, and G. granulata; *d, d, d*, G. biseriata (side view); *b, b*, Surirella plicata; *c*, S, craticula; *k*, S, caledonica; *e*, Gomphonema gracile; *f*, Cocconema fusidium; *g*, Tabellaria vulgaris; *h*, Pinnularia dactylus; *i*, P. nobilis; *l*, Synedra ulna. (From Carpenter.)

the deposit called in Sweden and Norway *berg-mehl* or mountain flour, because used in times of scarcity to mix with flour for bread, are similarly composed. Strata of white rock in the anthracite region of Pennsylvania, and from the sides of the Sierra Nevada and Cascade ranges in California and Oregon, have also been found to consist of such remains (Fig. 53).

The lowest type of animal life, consisting of minute portions of sarcode or animal jelly, having the power of putting forth prolongations of the body at will, contain some forms which cover themselves with shells, usually many-chambered, of carbonate of lime. From the pores in these shells, through which the root-like processes of sarcode are protruded, they are called *Foraminifera.*

Fig. 54.

Fossil Polycystina, etc., from Barbadoes: *a*, Podocyrtis mitra; *b*, Rhabdolithus sceptrum; *c*, Lychnocanium falciferum; *d*, Encyrtidium tubulus; *e*, Flustrella concentrica; *f*, Lychnocanium lucerna; *g*, Encyrtidium elegans; *h*, Dictyospyris clathrus; *i*, Encyrtidium mongolfieri; *k*, Stephanolithis spinescens; *l*, S, nodosa; *m*, Lithocyclia ocellus; *n*, Cephalolithis sylvina; *o*, Podocyrtis cothurnata; *p*, Rhabdolithes pipa. (From Carpenter.)

Another class, the *Polycystina*, secrete a siliceous shell, usually of one chamber. The accumulations of the Foraminifera have formed our chalk beds, while the Polycystina have contributed to siliceous strata, like the *Diatomaceæ* (Fig. 54).

The origin of white chalk strata has been illustrated

by the deep-sea soundings made preparatory to laying the telegraph cable across the Atlantic Ocean. Professor Huxley found the mud composing the floor of the ocean to consist of minute Rhizopods or Foraminifera, of the genus *Globigerina*, together with Polycystina and Diatoms, and a few siliceous spiculæ of sponges. These were connected by a mass of living gelatinous matter, to which he has given the name of *Bathybius*, and which contains minute bodies termed *Coccoliths* and *Coccospheres*, which have also been detected in fossil chalk. It is said that 95 per cent. of the mud of the North Atlantic consists of Globigerina shells.

To examine Foraminifera in chalk, rub a quantity to powder in water with a soft brush, and let it settle for a variable time. The first deposits will contain the larger specimens, with fragments of shell, etc.; the smaller fall next, while the amorphous particles suspended in the water may be cast aside. After drying such specimens as may be selected by the use of a dissecting microscope or Coddington lens, etc , they may be mounted in balsam.

The flint found in chalk often contains Xanthidia, which are the sporangia of Desmidiaceæ, as well as specimens of sponge, Foraminiferal shells, etc. They must be cut as other hard minerals.

There are other deposits besides chalk which are seen by the microscope to consist of minute shells, corals, etc. A section of oolitic stone will often show that each rounded concretion is composed of a series of concentric spheres inclosing a central nucleus which may be a foraminiferal shell. The green sand formation is composed of the casts of the interior of minute shells which have themselves entirely disappeared. The material of these casts, chiefly silex colored with iron, has not only filled the chambers of the shells, but has penetrated the canals of the intermediate skeleton.

The more recent discovery by Drs. Dawson and Carpen-

ter of the organic nature of those serpentine limestones in the Laurentian formations of Canada and elsewhere, which are products of the growth of the gigantic foraminiferal *Eozoon Canadense*, over immense areas of the ancient sea-bottom, is one of still greater interest both to the student of Geology and of Biology.

This immense rhizopod appears to have grown one layer over another, and to have formed reefs of limestone as do the living coral-polyps. Parts of the original skeleton, consisting of carbonate of lime, are still preserved, while certain interspaces have been filled up with serpentine and white augite.

Microscopic Palæontology.—As a general rule it is only the hard parts of animal bodies that have been preserved in a fossil state.

It will often occur that the inspection of a microscopic fragment of such a fossil will reveal with certainty the entire nature of the organism to which it belonged. Thus minute fossil corals, the spines of Echinodermata, the eyes of Trilobites, etc., will determine the position to which we should ascribe the specimen, or a section of tooth or bone will enable the microscopist to assign the fossil to its proper class, order, or family. Thus Professor Owen identified by its fossil tooth, the *Labyrinthodon* of Warwickshire, England, with the remains in the Wittemberg sandstones, and declared it to be a gigantic frog with some resemblances both to a fish, and a crocodile. This prediction the subsequent discovery of the skeleton confirmed.

The minute structure of teeth differs greatly in different animals. In the shark tribe of fishes the dentine is very similar to bone, excepting that the lacunæ of bone are absent. In man and in the Carnivora the enamel is a superficial layer of generally uniform thickness, while in many of the Herbivora the enamel forms with the cementum a series of vertical plates which dip into the substance of the dentine. Enamel is wanting in serpents, Edentata,

and Cetacea. Such differences make it quite possible to distinguish the affinities of a fossil specimen from a small fragment of tooth.

In a similar way the microscopic characters of bone vary. The bones of reptiles and fishes have the cancellated structure throughout the shaft, while the lacunæ present very great varieties, so that an animal tribe may be determined by their measurement. In this way many contributions have already been made to palæontology.

CHAPTER VIII.

THE MICROSCOPE IN CHEMISTRY.

THE value of microchemical analysis, and the simplicity of its processes, commend this department of microscopy to general favor.

A large proportion of the actions and changes produced by reagents may be observed as satisfactorily in drops as in larger quantities. The decompositions effected by a galvanic battery far smaller than that contained in a lady's silver thimble, which deflected the mirror at the other end of the Atlantic Telegraph Cable, may be readily observed with a microscope.

Apparatus and Modes of Investigation.—A few flat and hollow glass slides, thin glass covers, test-tubes, small watch-glasses, a spirit-lamp or Bunsen's burner, constitute nearly all the furniture which is essential.

Dr. Wormley* directs that a drop of the solution to be examined should be placed in a watch-glass, and a small portion of reagent added with a pipette. The mixture

* The Microchemistry of Poisons, by Dr. Wormley.

may then be examined with the microscope. If there is no precipitate, let it stand several hours and examine again. Dr. Beale prefers a flat or concave slide, and suggests that if a glass rod be used for carrying the reagent, it must be washed each time, or a portion may be transferred from the slide to the bottle. He also advises the use of small bottles with capillary orifices for reagents. Dr. Lawrence Smith uses small pipettes with the open end covered by india-rubber.

If heat be required, the drop may be boiled on the slide over a spirit-lamp, or a strip of platinum-foil or mica may be held with forceps so as to get a red or white heat from the lamp or a Bunsen burner. This is especially needed to get rid of organic matters.

For the examination of earthy materials, as carbonate or phosphate of lime, phosphate of ammonia and magnesia, sulphates or chlorides, a small fragment may be placed on a slide and covered with thin glass. A drop of nitric acid is then put near the edge of the cover. If bubbles escape a carbonate is indicated. Neutralize the acid with ammonia; let the flocculent precipitate stand awhile; cover and examine with the microscope. After a time, amorphous granules and prisms will show phosphates of ammonia, magnesia, and lime. Sulphates are shown by adding to the nitric acid solution nitrate of barytes, and chlorides by nitrate of silver.

Dr. Beale recommends adding glycerin to the test solutions. The reactions are slower but more perfect, and the crystalline forms resulting are more complete.

If a sublimate be desired, a watch-glass can be inverted over another, and the lower one containing the material, as biniodide of mercury, etc., heated over a spirit-lamp, or the sublimation may be made in a reduction-tube.

Preparation of Crystals for the Polariscope.—Many specimens may be prepared by concentrating the solution with heat and allowing it to cool. It should not be evaporated

to dryness. Many salts may be preserved in balsam, but some are injured by it, and need glycerin or castor oil as a preserving fluid.

The method of crystallization may be modified in various ways so as to obtain special results. Thus if a solution of sulphate of iron is suffered to dry on a slide, the crystals will be arborescent and fern-like, but if the liquid is stirred with a glass rod or needle while evaporating, separate rhombic prisms will form, which give beautiful colors in the polariscope. Pyrogallic acid also crystallizes in long needles, but a little dust, etc., as a nucleus, brings about a change of arrangement resembling the "eye" of the peacock's tail.

A saturated solution dropped into alcohol, if the salt is insoluble in alcohol, will produce instantaneous crystals.

To obtain the best results, some crystals, as salicin, should be fused on a slide over the lamp, and the matter spread evenly over the surface. This may be done with a hot needle. The temperature greatly affects the character of the crystallization. If very hot, the crystals run in lines from a common centre. A medium temperature produces concentric waves.

Many new forms result from uniting different salts in different proportions. The knowledge of these different effects can only be attained by experience.

Sections of crystals, as nitrate of potash, etc., to show the rings and cross in the polariscope, are difficult to make. After cutting a plate with a knife to about one-fourth of an inch thick, it may be filed with a wet file to one-sixth of an inch, smoothed on wet glass with fine emery, and polished on silk strained over a piece of glass, and rubbed with a mixture of rouge and tallow. The nitre must be rubbed till quite dry, and the vapor of the fingers prevented by the use of gloves.

For a general account of the use of polarized light, see Chapter VI.

The Use of the Microspectroscope.—We have already described this accessory in Chapter III. It promises important results in chemical analysis, but requires delicate observation and exact measurements, together with a careful and systematic study of a large number of colored substances.

In using the microspectroscope, much depends on the regulation of the slit. It should be just wide enough to give a clear spectrum without irregular shading. As a general rule, it should be just wide enough to show Frauenhofer's lines indistinctly in daylight. The slit in the side stage should be such that the two spectra are of equal brilliancy. No light should pass up the microscope but such as has passed through the object under examination. This sometimes requires a cap over the object-glass, perforated with an opening of about one-sixteenth of an inch for a one and a half inch objective.

The number, position, width, and intensity of the absorption-bands are the data on which to form an opinion as to the nature of the object observed, and Mr. Sorby has invented a set of symbols for recording such observations. (See Dr. Beale's *How to Work with the Microscope.*) These bands, however, do not relate so much to the elementary constitution as to the physical condition of the substance, and vary according to the nature of the solvent, etc., yet many structures give such positive effects as to enable us to decide with confidence what they are.

Colored beads obtained by ordinary blowpipe testing, sections of crystals, etc., cut wedge-shaped so as to vary their thickness, often give satisfactory results. But minute quantities of animal and vegetable substances, as blood-stains, etc., dissolved and placed in short tubes fastened endwise on glass slides, or in some other convenient apparatus, offer the most valuable objects of research.

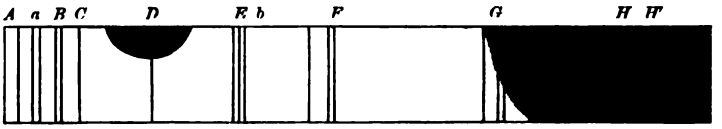
To measure the exact position of the absorption-bands,

the micrometer already described may be used, or Mr. Sorby's apparatus, giving an interference spectrum with twelve divisions, made by two Nicol's prisms, with an intervening plate of quartz of the required thickness.

The value of this mode of investigation in medical chemistry, and for purposes of diagnosis or jurisprudence, may be seen by the following illustrations:*

Pettenkofer's Test for Bile (Fig. 55).—To a few drops of bile in a porcelain dish, add a drop of solution of cane-

FIG. 55.

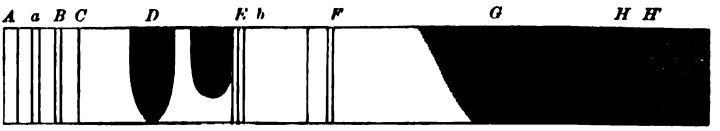


Pettenkofer's Bile-Test.

sugar, and then concentrated sulphuric acid drop by drop, with agitation. The mixture becomes a purple-red color, and shows a spectrum as in the figure. The color will be destroyed by water and alcohol.

Tests for Blood.—Hæmatocrystalline, or cruorin, composed of an albuminoid substance and hæmatin, generally crystallizes in tetrahedra or octahedra. In blood from

FIG. 56.



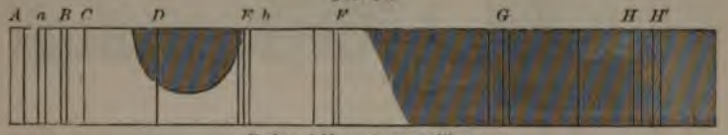
Blood.

the horse and from man only an amorphous deposit is found. The watery solution of this substance properly diluted, shows two remarkable bands of absorption, and obscuration of the blue and violet end of the spectrum (Fig. 56). As the blood of all vertebrates shows the same

* See Thudichum's Manual of Chemical Physiology. New York, 1872.

bands, it is judged that hæmatocrystalline is present in it as such, and not formed from it. By treating a solution of blood which exhibits the two absorption-bands with hydrogen, or with a solution of ferrous sulphate containing tartaric acid and excess of ammonia, taking care to

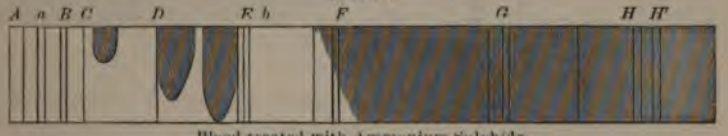
FIG. 57.



Reduced Hæmatocrystalline.

exclude the air, the color of the solution changes to purple, and the spectroscope shows only one broad band instead of two (Fig 57). Shaking with air will restore the two bands. By treating blood with hydrothion or am-

FIG. 58.

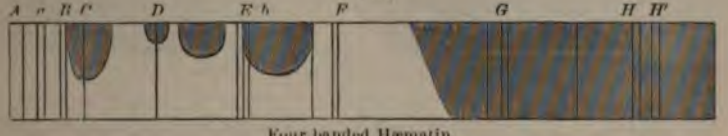


Blood treated with Ammonium Sulphide.

monium sulphide, three bands make their appearance, as in Fig. 58.

Hæmatin is seen by the microscope to consist of small

FIG. 59.



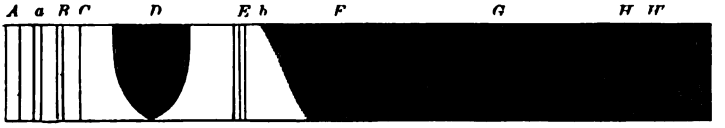
Four banded Hæmatin.

rhombic crystals. Dissolved in alcohol and a little sulphuric acid, the spectrum shows four, and under some circumstances five, bands (Fig. 59). Rendered alkaline

by caustic potash, one broad band appears (Fig. 60). Acid will restore the former spectrum.

Dissolve hæmatin in water with a little caustic potash.

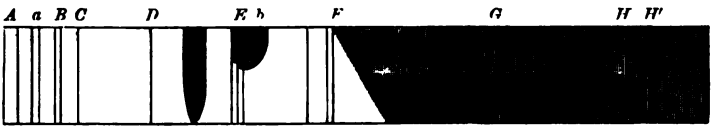
Fig. 60.



Alkaline Hæmatin.

To a solution of ferrous sulphate, add tartaric acid and then ammonia till alkaline. Pour a little of the clear mixture into the hæmatin solution. The spectrum of re-

Fig. 61.

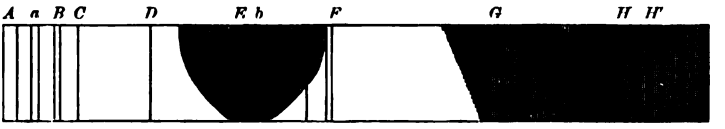


Reduced Hæmatin.

duced hæmatin will show two bands (Fig. 61). Shaking with air will restore the former spectrum.

Lutein Spectra.—The juice of the corpora lutea, to which sulphuric acid and a little sugar is added, gives a fine

Fig. 62.

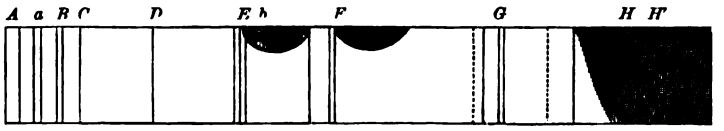


Juice of Corpora Lutea with Sulphuric Acid.

purple color, and shows in the spectroscope one band in the green (Fig. 62). Its chloroform solution, examined with lime-light, shows two bands in blue (Fig. 63). An alcoholic or ethereal solution gives a third one in the violet.

Cysto lutein, or the yellow fluid of an ovarian cyst, shows with the lime-light three bands in blue, in the

Fig. 63.

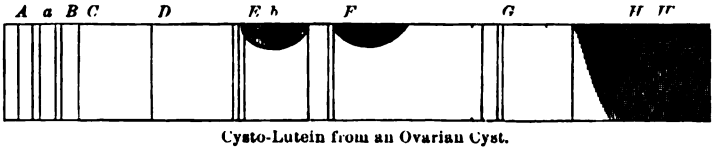


Chloroform Solution of Corpora Lutea.

same position as the chloroform solution of lutein (Fig. 64).

The serum of blood, etc., shows the bands of hæmato-

Fig. 64.

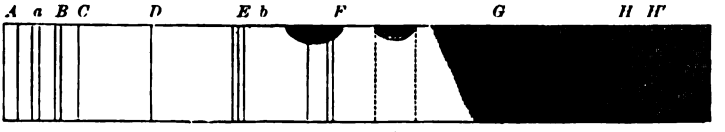


Cysto-Lutein from an Ovarian Cyst.

crystalline and one or two doubtful bands, as in the figure (Fig. 65).

Dr. Richardson, of Philadelphia, gives the following directions for examining blood-stains: Procure a glass slide with a circular excavation, and moisten the edges of the cavity with a small drop of diluted glycerin. Lay

Fig. 65.



Sero-Lutein.

a clean glass cover, a little larger than the excavation, on white paper, and put on it the smallest visible fragment of blood-clot. With a needle, put on the centre of the cover a speck of glycerin, not larger than a full stop (.),

and with a dry needle push the blood to the edge that it may be just moistened with the glycerin. Place the slide on the cover so that the glycerin edges of the cavity may adhere, and turning it over, transfer it to the stage of the microscope. Thus a minute quantity of a strong solution of hæmoglobulin is obtained, the point of greatest density of which may be found by a one-fourth objective, and tested by the spectroscopic eye-piece and with high powers. The tiny drop may be afterwards wiped off with moist blotting-paper, and a little fresh tincture of guaiacum added, showing the blue color of the guaiacum blood-test.

Inverted Microscope of Dr. Lawrence Smith.—In ordinary chemical investigations there is some risk of injuring the polish of the lenses, as well as the brass work of the microscope, without very great care. This is particularly the case in observing the effects of heat or of strong acids. To obviate this difficulty, Dr. Lawrence Smith contrived a plan for an inverted microscope, which has been constructed by Nachet of Paris. The optical part of the instrument is below the stage, and is furnished with a peculiar prism, by which the rays from the objective are bent into a conveniently inclined body. The illuminating apparatus is above the stage. This construction renders the instrument well adapted to chemical investigations.

General Microchemical Tests.

Dr. Wormley has directed attention to some necessary cautions. He shows that many substances which may readily be detected in a pure state, even in very minute quantities by the microscope, are difficult to detect when mixed with complex organic materials. This is especially applicable to the alkaloids, which should be separated from such mixtures by the use of the dialyzer—a hoop with a bottom of parchment-paper, etc.—or extracted with ether or chloroform.

The purity of all reagents should be carefully established, and they should be kept in hard German glass bottles, and only distilled water used in all our researches.

The true nature of a reaction that is common to several substances may often be determined with the microscope. Thus a solution of nitrate of silver becomes covered with a white film when exposed to several different vapors, but hydrocyanic acid is the only one which is crystalline. This will detect 100,000th of a grain of the acid. A slip of clean copper boiled in a hydrochloric acid solution of arsenic, mercury, antimony, etc., becomes coated with the metal, but when heated in a reduction-tube, arsenic only yields a sublimate of octahedral crystals, and mercury only will furnish metallic globules.

A solution of iodine produces distinct reaction with 100,000th of a grain of strychnine in solution in 1 grain of water, but as this is common to other alkaloids, other tests are needed. Yet the absence of such a reaction shows the absence of the alkaloid.

The degree of dilution is important. Thus bromine with atropin yields a crystalline deposit from 1 grain of a 20,000th or stronger dilution, but not with diluter solutions. A limited quantity of sulphuretted hydrogen throws down from corrosive sublimate a white deposit, while excess produces a black precipitate.

Blue and Reddened Litmus Paper are used as tests for acids and alkalies. It is a bibulous paper dyed in infusion of litmus. The red is made by adding a little acetic acid to the infusion. Dry substances and vapors require the paper to be moistened with distilled water. If the acid reaction depends on carbonic acid, warming the paper on a slide over a lamp will restore the color. So if a volatile alkali, ammonia or carbonate of ammonia, have made the red paper blue, its color will be restored by a gentle heat. Sometimes the infusion of litmus is more convenient than the paper.

Alcohol coagulates albuminous matter.

Ether dissolves fat.

Acetic Acid will dissolve phosphate or carbonate of lime, but not the oxalate.

Nitrate of Barytes in cold saturated solution is a test for sulphuric and phosphoric acids. The precipitated sulphate of baryta is insoluble in acids and alkalies. The phosphate is soluble in acids and insoluble in ammonia.

Nitrate of Silver.—A solution of 60 grains to the ounce of water is a convenient test for chlorides and phosphates. Chloride of silver is white, soluble in ammonia and insoluble in nitric acid. The tribasic phosphate of silver is yellow, and soluble in excess of ammonia or of nitric acid.

Oxalate of Ammonia is a test for salts of lime. Dissolve the material in nitric acid, and add excess of ammonia. Dissolve the flocculent precipitate in excess of acetic acid, and add the oxalate of ammonia. Oxalate of lime is insoluble in alkalies and acetic acid, but soluble in strong mineral acids.

Iodine is a test for starch, coloring it blue. Albuminous tissues are colored yellow, and vegetable cellulose a brownish-yellow. The addition of sulphuric acid turns cellulose blue.

Determination of Substances.

ALKALIES.

Bichloride of platinum precipitates from salts of potash or ammonia a yellow double chloride, which crystallizes in beautiful octahedra. It has no precipitating effect on solutions of soda. Polarized light will distinguish the 800,000th of a grain of double chloride of sodium and platinum by its beautiful colors from the chloride of potassium and platinum, or of platinum alone. The double chloride of platinum and potassium may be distinguished from that of ammonia by heating to redness, treating with hot water, and acting on with nitrate of

silver. The ammonium compound after ignition leaves only the platinum, which gives no precipitate with nitrate of silver, while the potassium chloride yields a white precipitate of chloride of silver.

Antimoniate of potash throws down from solutions of soda and its neutral salts a white crystalline antimoniate of soda, the forms of which vary according to the strength of the solution; generally they are rectangular plates and octahedra.

ACIDS.

Sulphuric.—In solutions acidulated with hydrochloric or nitric acid, the chloride or nitrate of baryta produces a white precipitate. Veratrin added to a drop of concentrated sulphuric acid produces a crimson solution, or deposit if evaporated.

Nitric.—Heated with excess of hydrochloric acid eliminates chlorine, which will dissolve gold leaf. A blood-red color is produced when nitric acid or a nitrate is mixed with a sulphuric acid solution of brucin.

Hydrochloric.—Nitrate of silver precipitates amorphous chloride of silver; soluble in ammonia, but insoluble in nitric and sulphuric acid.

Oxalic.—Nitrate of silver precipitates amorphous oxalate of silver; soluble in nitric acid and also in solution of ammonia.

Hydrocyanic.—Put a drop of acid solution in a watch-glass, invert another over it containing a drop of solution of nitrate of silver, and a crystalline film will form. A solution of hydrocyanic acid treated with caustic potash or soda and then with persulphate of iron yields Prussian blue.

Phosphoric.—A mixture of sulphate of magnesia, chloride of ammonium, and free ammonia produces in solutions of free phosphoric acid and alkaline phosphates white feathery or stellate crystalline precipitate of ammo-

nio-phosphate of magnesia. A slower crystallization gives prisms.

METALLIC OXIDES.

These may usually be determined by treating a small portion of solution, acidulated with hydrochloric acid, by sulphuretted hydrogen; another, and neutral portion with sulphuret of ammonium; and a third with carbonate of soda.

Antimony.—Sulphuretted hydrogen throws down orange-red precipitate from tartar-emetic solutions, etc.

Arsenic yields white octahedral crystals of arsenious acid when sublimed. Arsenious acid may be reduced to metallic arsenic by heating to redness in a tube with charcoal and carbonate of soda. A solution of arsenious acid yields octahedral crystals by evaporation, so as to determine with the microscope 1000th to 10,000th of a grain.

Ammonio-nitrate of silver throws down from an aqueous solution of arsenious acid a bright yellow precipitate, ammonio-sulphate of copper a green precipitate, and sulphuretted hydrogen a bright yellow.

Mercury.—Bichloride of mercury, moistened with a drop of solution of iodide of potassium, assumes the bright scarlet color of biniodide of mercury. A strong solution of caustic potash or soda turns bichloride of mercury yellow from the formation of protoxide; but calomel or chloride of mercury is blackened from formation of suboxide. Heated in a reduction-tube with dry carbonate of soda, the sublimate shows under the microscope small, opaque, spherical globules of mercury. Dr. Wormley states that a globule of mercury or "artificial star" may be discriminated by the one-eighth objective if it be but the 25,000th of an inch in diameter, weighing about the 9,000,000,000th of a grain; globules of $\frac{1}{50000}$th of an inch diameter weigh about 70,000,000th of a grain.

Lead.—Sulphuretted hydrogen gives a black amorphous deposit. Sulphuric and hydrochloric acids yield a white precipitate. Chloride of lead crystallizes in needles. Iodide of potassium gives a bright yellow precipitate, soluble in boiling water, and crystallizing in six-sided plates. Bichromate of potassium yields a bright yellow amorphous deposit.

Copper.—Sulphuretted hydrogen gives a brown or blackish deposit; ammonia a blue or greenish-blue amorphous precipitate, or in dilute solutions a blue color to the liquid; caustic alkali, a similar precipitate, which on boiling in excess of reagent becomes black, but if grape-sugar, or some other organic agents, be present, a yellow or red precipitate of suboxide of copper occurs. Arsenite of potassium produces a bright green.

Zinc.—Sulphuretted hydrogen gives a white amorphous deposit—the only white sulphuret. Alkalies produce a white hydrated oxide of zinc.

ALKALOIDS.

The editors of the *Micrographic Dictionary* refer to a paper of Dr. T. Anderson, in the *Edinburgh Monthly Journal*, where he shows that the microscope readily distinguishes the more common alkaloids from each other by the form of their crystals and of their sulphocyanides. The alkaloids are first dissolved in dilute hydrochloric acid, then precipitated on a glass plate with a solution of ammonia, or if the sulphocyanide is required, with a strong solution of sulphocyanide of potassium. It may then be placed under the microscope. The solution should not be too concentrated. This branch of investigation has been greatly promoted by the elegant work of Dr. Wormley, already referred to, on the *Microchemistry of Poisons.*

Atropin.—Ammonia throws down an amorphous precipitate. One grain of a $\frac{1}{100}$th grain solution yields to

caustic potash or soda a precipitate which, when stirred with a glass rod, becomes a mass of crystals, as in Plate III, Fig. 66. The sulphocyanide of potassium gives no precipitate.

Aconitin.—No characteristic test, except the physiological one; $\frac{1}{1000}$th of a grain produces on the end of the tongue a peculiar tingling and numbness, lasting for an hour; $\frac{1}{100}$th grain in alcohol, rubbed on the skin, produces temporary loss of feeling.

Brucin or Brucia.—Potash or ammonia produces stellar crystals. Sulphocyanide of potassium, feathery, or sheaf-like. (Plate III, Fig. 67.) Nitric acid produces a blood-red color, changing to yellow by heat. On cooling the latter and adding protochloride of tin, it becomes a beautiful purple. Ferricyanide of potassium, with $\frac{1}{100}$th grain of brucin yields the most brilliant polariscope crystals. (Plate III, Fig. 68).

Cinchonine.—Ammonia produces granular radiating crystals. (Plate III, Fig. 69.) Sulphocyanide of potassium six-sided plates, some irregular. (Plate III, Fig. 70.)

Conine.—This alkaloid and nicotin are distinguished from other alkaloids by being liquid at ordinary temperatures, and by their peculiar odor. Conine may be known from nicotin by its odor and sparing solubility in water, by yielding crystalline needles to the vapor or solution of hydrochloric acid, a white precipitate with corrosive sublimate, and a dark-brown precipitate with nitrate of silver.

Codein.—Ammonia or alkalies give a white amorphous deposit. Sulphocyanide of potassium, crystalline needles. A solution of iodine in iodide of potassium, a reddish-brown precipitate, which becomes crystalline. This is soluble in alcohol, from which it separates in plates (Plate III, Fig. 71), which appear beautiful in the polariscope.

Daturin.—According to Dr. Wormley, this is identical with atropin.

Narcotin.—In its pure state crystallizes in rhombic

PLATE III.

Fig. 66.

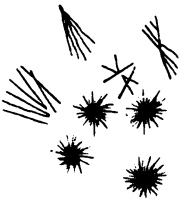


Fig. 67.

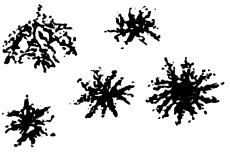


Fig. 68.

Fig. 69.

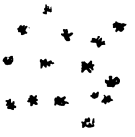


Fig. 70.

Fig. 71.

Fig. 72.

Fig. 73.

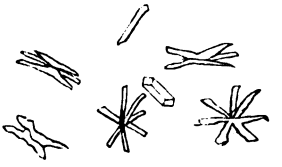


Fig. 74.

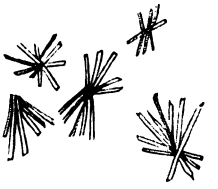
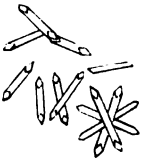


Fig. 75.



prisms, or oblong plates. Ammonia, the alkalies, and their carbonates produce tufts of crystals (Plate III, Fig. 72). A drop of aqueous solution of a salt of narcotin, exposed to vapor of ammonia, is covered with a crystalline film if it only contains $\frac{1}{50}$'$_{00}$th of its weight of alkaloid.

Morphine.—When pure crystallizes in short rectangular prisms. Sulphuric acid dissolves them, and if bichromate of potash be added, green oxide of chromium results. Concentrated nitric acid turns it orange-red, and dissolves it. A strong solution treated with a strong solution of nitrate of silver and gently heated, decomposes the latter and produces a shining crystalline precipitate of metallic silver. In dilute solutions, alkalies precipitate a crystalline form (Plate III, Fig. 73). No precipitate with sulphocyanide of potassium unless highly concentrated.

Quinine.—Amorphous precipitate with ammonia. Sulphocyanide of potassium gives irregular groups of acicular crystals, like those produced by strychnine, but longer and more irregular (Plate III, Fig 74). The solution should be dilute, and twenty-four hours allowed for the crystals to form.

The iodo-disulphate, or Herapathite, gives crystals of a pale olive-green color, which possess a more intense polarizing power than any other known substance. Dr. Herapath proposed this as a delicate test for quinine. A drop of test-liquid—made with 3 drachms of acetic acid, 1 drachm of rectified spirits, and 6 drops of dilute sulphuric acid—is placed on a slide and the alkaloid added. When dissolved a little tincture of iodine is added, and after a time the salt separates in little rosettes. By careful manipulation crystals of this salt may be formed large enough to replace Nicol's prisms or tourmaline plates in the polarizing apparatus. When the crystals of Herapathite cross each other at a right-angle, complete blackness results. Intermediate positions give a beautiful play of colors.

Strychnine.—Ammonia gives small prismatic crystals,

some crossed at 60° (Plate III, Fig. 75). Sulphocyanide of potassium produces flat needles, often in groups. Iodine in iodide of potassium gives a reddish-brown amorphous precipitate, crystalline in dilute solutions. When pure, strychnine appears in colorless octahedra, lengthened prisms or granules. To a solution of the alkaloid or its salts in a drop of pure sulphuric acid, which produces no color, add a small crystal of bichromate of potash, and stir slowly with a pointed glass rod. A blue color will appear, passing into purple, violet, and red. The bright yellow crystals of chromate of strychnia, if dried and touched with sulphuric acid, will also show the color test. This is said to be delicate enough to show $\frac{1}{100000}$th of a grain of strychnine. The tetanic convulsions of frogs immersed in a solution of strychnine, or after injections of the solution in lungs or stomach, etc, is also a very delicate test.

Veratrin and its salts treated in the dry state with concentrated sulphuric acid, slowly dissolve to a reddish-yellow, or pink solution, which becomes crimson-red. The process is accelerated by heat.

Narcein, touched with the cold acid, becomes brown, brownish-yellow, and greenish-yellow, and if heated, a dark purple-red.

Solanin turns orange-brown, and later purplish-brown.

Piperin turns orange-red to brown.

Salicin gives to the acid a crimson pink, changing to black.

Papaverin gives a fading purple.

CRYSTALLINE FORMS OF VARIOUS SALTS.

Our limits forbid extended description, yet a few forms of frequent recurrence will be useful to the student. For crystals in plants or from animal secretions reference may be made also to succeeding chapters.

Salts of Lime.—The *carbonate* sometimes occurs in ani-

PLATE IV.

FIG. 76.

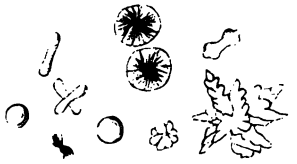


FIG. 77.

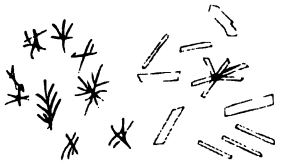


FIG. 78.

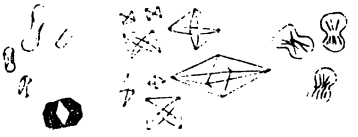


FIG. 79.

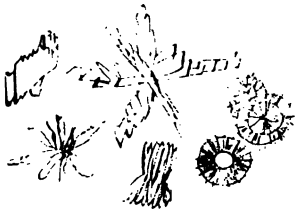


FIG. 80.

FIG. 81.

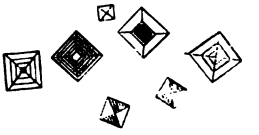
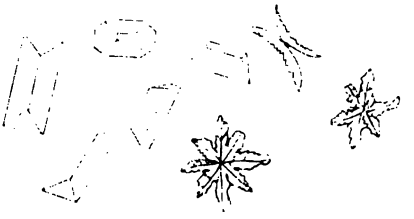


FIG. 82.

FIG. 83.

FIG. 84.



mal secretions in the form of little spheres or disks, consisting of groups of radiating needles. In otoliths it is often in minute hexagonal prisms with trilateral summits. It is deposited from water in irregular forms, all of which are grouped needles. Sometimes it assumes the rhombohedral form, as in the oyster shell (Plate IV, Fig. 76). In any doubtful case, test as described at pages 99 and 108.

Lactate of Lime gives microscopic crystals, consisting of delicate radiating needles (Plate IV, Fig. 77).

Oxalate of Lime occurs as square flattened octahedra, as square prisms with quadrilateral pyramids, as fine needles, and as ellipsoidal flattened forms, sometimes constricted so as to resemble dumb-bells (Plate IV, Fig. 78).

Phosphate of Lime is usually in the form of thin rhombic plates (Plate IV, Fig. 79).

Sulphate of Lime rapidly formed, as in chemical testing, gives minute needles or prisms (Plate IV, Fig. 80). When more slowly formed, these are larger and mixed with rhombic plates.

Soda Salts.—Chloride of Sodium or common salt generally forms a cube, terminated by quadrangular pyramids or depressions (Plate IV, Fig. 81). The crystals do not polarize light.

Plate IV, Fig. 82, represents crystals of *oxalate* of soda, and Plate IV, Fig. 83, those of *nitrate*.

Magnesia Salts.—Ammonio-phosphate, or triple phosphate, is often found in animal secretions. The most common form is prismatic, but sometimes it is feathery or stellate (Plate IV, Fig. 84).

Sulphate of Magnesia forms an interesting polarizing object.

A most instructive series of salts may be made by rapidly crystallizing some on glass slides, and allowing others to deposit more slowly. In this way a set of specimens may be prepared for comparison.

CHAPTER IX.

THE MICROSCOPE IN BIOLOGY.

The science of biology (from βιος, life), which treats of the forms and functions of living beings, would be crude and imperfect without the aid of the microscope. Whatever might be learned by general observation, we should miss the fundamental laws of structure and the unity which we now know pervades distant and apparently different organs, as well as distinct species, if we were deprived of the education which microscopy gives the eye and hand.

The evident differences between living and non-living bodies led to ancient theories of life which are still influential in modern thought, but neither microscope nor scalpel nor laboratory have revealed the mystery which seems ever to beckon us onward to another and entirely different sphere of existence. Hippocrates invented the hypothesis of a principle (φυσις, or nature) which influences the organism and superintends it with a kind of intelligence, and to which other principles (δυναμεις, powers) are subordinated for the maintenance of various functions. This was also the theory of Aristotle, who gave the name of soul (ψυχη) to the animating principle.

Paracelsus and the chemical philosophers, from the fifteenth to the seventeenth century, maintained that all the phenomena of vitality may be explained by chemical laws. To these succeeded the mathematical school under Bellini (A.D. 1645), who taught that all vital functions may be explained by gravity and mechanical impulse. These theories were supplanted by those of the physiologists. Van Helmont revived the Hippocratian idea of a specific agent, which he called *archeus*. This was more fully elaborated by Stahl, who taught that by the opera-

tion of an immaterial animating principle or soul (*anima*), all vital functions are produced. The *vis medicatrix naturæ* of Cullen was an attempt to compromise between the rival theories of a superadded principle and a special activity in organized matter itself.*

Harvey, Hunter, Müller, and Prout proposed hypotheses similar to those of Aristotle and Hippocrates, and many modern scientific men accept similar views. The recent doctrine of the correlation of physical forces has, however, revived the mechanical and chemical theories, and the industry with which these views have been propagated has gained many adherents.

It is to be regretted that philosophy should assume the name of science and dogmatize under that appellation. The object of science is to state facts, and not to dream, yet such is the nature of man's intellect that it will seek to account for facts, and is thus drawn into metaphysical speculation. If the age-long controversy between the physicists and the vitalists is ever to cease, it will probably be through the microscopic demonstration of the absolute difference between living and non-living matter.

In the present chapter it is designed to set forth briefly the principal facts of elementary biology as they have been brought to light by microscopy. For further illustrations in vegetable and animal histology, reference may be made to following chapters.

1. All biologists agree that *the elementary unit in living bodies* is the cell. This, according to the most recent investigations, is a soft, transparent, colorless, jelly-like particle of matter, which may be large enough to be just discernible to the naked eye, or so small as to be invisible with our best instruments. The simplest or most elementary forms of vegetable or animal life consist of single cells, while the more complex organisms are built up of

* Compare Bostock's History of Medicine.

great numbers of these cells with the materials which they have produced and deposited.

Haller, who has been called the father of modern physiology, seems first to have conceived, though vaguely (A.D. 1766), the idea of the essential unity of vital structure.

In 1838, Schleiden and Schwann wrote on the elementary cell, the former treating of the vegetable, and the latter of the animal cell. From this time may be dated the origin of the cell doctrine. Much importance was assigned to the distinction between cell-wall, cell-contents, nuclei, and nucleoli.

In 1835, Dujardin discovered in the lower animals a contractile substance capable of movement, to which he gave the name of *sarcode*.

In 1861, Max Schultze showed that sarcode is analogous to the body or contents of animal cells, and that on this account the infusorial animalcules possessed of independent life were simple or compound.

Examinations of this structure were made by numerous observers, and the identity of many of its properties in animals and vegetables established. To this structure the name of *protoplasm*, rather than sarcode, has been assigned. As this term has been somewhat loosely used, so as to refer to it either in the dead or living state, Dr. Beale has proposed the term *bioplasm* for elementary structure while living, and has given a generalization from observed facts, which has attracted much attention. He distinguishes in all organic forms three states of matter: First. Germinal matter or *bioplasm*, or matter which is living. Second. Matter which was living, or *formed material*. Third. Matter about to become living, or *pabulum*.

Schleiden and Schwann considered the cell as a growth from a nucleus, and to consist of a cell-wall and cavity. In vegetable cells there seemed to be an external wall of cellulose, within which was another, the primordial utri-

cle. But it has since been shown that the appearance of the primordial utricle is caused by the protoplasm or bioplasm lying in apposition with the inner surface of the cell-wall. In the cryptogamia, cells are known to occur in which no nucleus is visible. Max Schultze and Häckel have also discovered non-nucleated forms of animal life. The idea of nucleus and cell-wall as essential to a cell is therefore abandoned. Nuclei are regarded as new centres of living matter, or minute particles of such matter capable of independent existence. Some of these masses are so small as to be barely visible with the one-fiftieth objective under a magnifying power of five thousand diameters.

2. *The structure and formation of a simple cell* may be illustrated by Plate V, Figs. 85 to 89, after Beale.* The earliest condition of such a living particle is shown in Plate V, Fig. 85. If the external membrane of a fully developed spore or any of the growing branches (Plate V, Figs. 86 to 89) be ruptured, such particles would be set free in vast numbers.

The surface of such a particle becomes altered by contact with external agencies. A thin layer of the external surface is changed into a soft membrane or cell-wall, through which pabulum passes and undergoes conversion into living matter, which thus increases. The increase of size is not owing to the addition of new matter upon the external surface, but to the access of new matter interiorly. The thickness of the formed material depends on external circumstances, as temperature, moisture, etc. If these be unfavorable to the access of pabulum, layer after layer of living matter will die or be deposited, as in Plate V, Figs. 87 and 88. If such a cell be exposed to circumstances favorable to growth, the accession of fresh pabulum will cause portions of living matter to make

* Physiological Anatomy and Physiology of Man, by Drs. Todd, Bowman, and Beale. New edition.

their way through natural pores or chance fissures and protrude, as in the figures.

3. *The peculiar phenomena of living cells* or bioplasms may be classified as follows: Active or spontaneous movement, nutrition and growth, and the power of reproduction. These vital actions, according to Dr. Beale, occur in the bioplasm only, while the formed material, or non-living matter, is the seat of physical and chemical changes exclusively. Physical processes, as diffusion and osmose, occur in bioplasmic particles, but the peculiar phenomena referred to, and which are properly termed vital, do not occur in non-living matter.

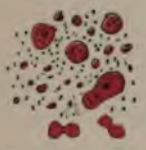
Movements of Cells.—Granules imbedded in the bioplasm, either formed material or accidental products, enable our microscopes to observe internal movement, while change of form and of place exhibit the movement of the entire cell.

The granular movement is either vibratory or continuous. The vibrations of the granules appear similar to the molecular movement described by Dr. Robert Brown in 1827, and which is common to all small masses of matter, organic or inorganic. Minute cells may thus dance in fluid as well as fine powders, etc. Such movements occur, however, in the interior of living cells, and may possibly be connected with vitality. In the salivary corpuscles, the dancing motion ceases on the addition of a solution of one-half to one per cent. of common salt, while such addition has no influence of the kind on fresh pus or lymph.

The continuous granular motion is either a relatively slow progression, corresponding to the change of form in the cell, or a swifter flowing movement. Max Schultze thus describes this motion in the threads of sarcode projected from the apertures of a Foraminiferal shell: "As the passengers in a broad street swarm together, so do the granules in one of the broader threads make their

PLATE V.

FIG. 85.



Minute particles of Bioplasm. From Mildew. $\frac{1}{50}$th in. Obj.

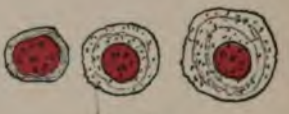
FIG. 88.

Passage of Germinal-matter through pores in the formed material. X 1800.

FIG. 86.

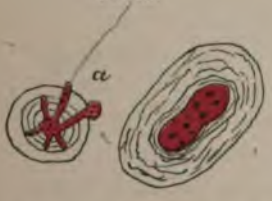
Production of formed-material on surface of Bioplasm. X 1800.

FIG. 89.



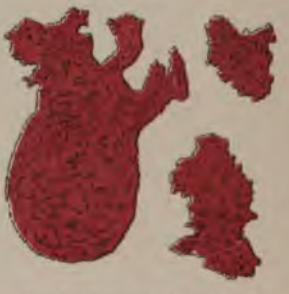
Production and accumulation of Formed-material on Bioplasm. Epithelium of cuticle. X 700.

FIG. 87.



Further production of formed-material. At *a* is the budding Bioplasm, passing through pores in the formed-material. X 1800.

FIG. 90.



Amœbœ from organic infusion.

way by one another, oftentimes stopping and hesitating, yet always pursuing a determinate direction corresponding to the long axis of the thread. They frequently become stationary in the middle of their course, and then turn round, but the greater number pass to the extreme end of the thread, and then reverse the direction of their movement." No physical or chemical action with which we are acquainted will account for such motions, which have no analogy in unorganized bodies.

Changes of form are most strongly marked in the lower forms of animal life, although occurring also in the simpler vegetables, as the volvox. The *Amœba* or Proteus is typical of such changes, which have hence been termed *Amœboid* (Plate V, Fig. 90). When an Amœba meets another animal which is too slow to escape, it sends out projections which encircle its prey; these coalesce, and invest the whole mass with its bioplasm. It maintains its grasp till it has abstracted all the portions which are soluble, and then relaxes its hold.

Amœboid cells in higher animals rarely move so rapidly as the Amœba itself. Their motions are limited to a gradual change of form or to the protrusion of processes in the form of threads, or tuberosities, or tufts, which either drag the rest of the body after them or are again withdrawn.

Cells of bioplasm may not only change their form, but may wander from place to place by protruding a portion of their mass, which drags the rest after it. The discovery of wandering cells in the higher organisms, as man, has opened quite a new and important field of physiological and pathological research.

The movements of bioplasm may be changed, accelerated, retarded, or stopped by a variety of stimuli, mechanical, electrical, chemical, and nervous. Gentle warmth and moisture are necessary to their perfection.*

* See Stricker's Manual of Histology.

The nutrition and growth of the living cell has already been described as the conversion of pabulum into bioplasm or living matter. The subject of reproduction will be examined below under the head of *cell-genesis.*

4. *The microscopic demonstration of bioplasm* may be effected by the use of an alkaline solution of coloring matter, as carmine. (See Chapter V.) As bioplasm possesses an acid reaction, the alkali is neutralized and the color retained. This process, however, is rather a demonstration of the protoplasm which was recently alive. For living cells or bioplasm, we must depend on supplying them artificially with colored food. Thus indigo, carmine, etc., in fine particles, added to the pabulum of cells or liquid media in which they float, will be taken into the interior of the bioplasm by the nutritive process. In this way Recklinghausen showed the migration of pus-corpuscles.

Welcker and Osborne were the first to use a solution of carmine in order to stain the nuclei of tissues. They were followed by Gerlach and Beale, the latter of whom has greatly improved the process and shown its significance.

5. *The chemistry of cells and their products* is an essential part of biology, but would lead us too far from our subject to discuss, yet a few points may not be irrelevant.

The chemical composition of bioplasm consists essentially of oxygen, hydrogen, nitrogen, and carbon. Other elements are often present and important, but not essential. Of the relation of these elements we know nothing, save that they are in a state of constant vibration or change. Dr. Beale considers it doubtful if ordinary chemical combination is possible while the matter lives. Analysis in the laboratory is only possible with the compounds resulting from the death of the cell.

When living or germinal matter is converted into formed material, a combination of its elements takes place, often

with very complex results, the nature of which has hitherto baffled the efforts of chemists to determine. When the life of germinal matter, however, is suddenly destroyed, or rather when the matter is first transformed, the compounds resulting from various species have similar chemical composition and properties, and an acid reaction is developed. Fibrin, albumen, water, and certain salts may thus be obtained from every kind of germinal matter. Fatty matters also result, which continue to increase in quantity for some time after death. In slow molecular death, a certain amount of oxygen is taken into combination, which gives rise to different results from those which occur when life is suddenly destroyed. Still other combinations are due to vital actions which are not yet understood. Thus some bioplasm produces muscle; other particles originate nerve structure, cartilage, bone, connective tissue, etc. Many chemical changes occur also in formed material after its production. It may become dry or fluid, or split up into gaseous or soluble substances as soon as produced. Imperfect oxidation may lead to the formation of fatty matters, uric acid, oxalates, sugar, etc. At the earliest period of development, the formed material consists principally of albuminous and fatty matters, with chlorides, alkaline and earthy phosphates. At a later period gelatin, with amyloid or starchy matter, is produced.*

6. *Varieties in the Form and Function of Bioplasm.*— Mutability of shape is characteristic of amœboid cells, and no conclusions can be drawn from their appearance after death. Where numbers of them are accumulated, they are flattened by mutual pressure so as to appear polyhedral, laminated, or prismatic. The upper layers of laminated epithelium are usually flattened. Where cells line the interior of cavities in a single layer, they form

* See Physiological Anatomy, by Todd, Bowman, and Beale.

plates of different shape (endothelial cells), or cells in which the long axis predominates (cylindrical epithelium), or forms which are intermediate between plates and cylinders. Some cells appear ramified or stellate, as in the cells from the pith of a rush, bone-cells, and corpuscles of the cornea. Others may become extraordinarily elongated, as in the formation of fibre, muscle, etc. Some cells are provided with cilia, which are limited to one portion of the surface, and project their free extremities into the cavity which they line. Dr. Beale considers the cilia to be formed material, and their movements not vital, but a result of changes consequent on vital phenomena.

Every living organism, plant, animal, or man, begins its existence as a minute particle of bioplasm. Every organic form, leaves, flowers, shells, and all varieties of animals; and every tissue, cellular, vesicular, hair, bone, skin, muscle, and nerve, originates by subdivision and multiplication and change of bioplasm, and the transformation or metamorphosis of bioplasm into formed material. It is evident, therefore, that there are different kinds of bioplasm indistinguishable by physics and chemistry, but endowed with different powers.*

7. *Cell-Genesis.*—Schleiden first showed that the embryo of a flowering plant originates in a nucleated cell, and that from such cells all vegetable tissues are developed. The original cells were formed in a plasma or blastema, commonly found in pre-existing cells, the nuclei first appearing and then the cell-membrane. These views were applied by Schwann to animal structure. The latter believed that the extra-cellular formation of cells, or their origin in a free blastema, was most frequent in animals. The researches of succeeding physiologists have, however, led to a general belief that all cells originate from other cells.

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* Beale's Bioplasm.

The doctrine of spontaneous generation or *abiogenesis* has been the object of considerable research, but the brilliant experiments of Pasteur have shown that when all access of living organisms into fluids is prevented, no development of such organisms can be proved in any case to occur. If the access of air, for instance, to a liquid which has been boiled, is filtered through a plug of cotton-wool, no living forms will appear in the liquid, but on examination, such forms will be found in considerable numbers in the cotton-wool, proving the presence of these forms or their germs in the external air. Recent experiments also render it probable that some cell-germs are indestructible by a heat far exceeding that of boiling water.

There are three forms of cell-multiplication, by fission, by germination or budding, and by internal division. The latter mode is termed endogenous. In it new cells are produced within a parent-cell by the separation of the bioplasm into a number of distinct masses, each of which may become a new cell, as in the fecundated ovum.

Fission, or the division by cleavage of a parent-cell into two or four parts, may be regarded as a modification of endogenous cell-multiplication. A good example of it may be seen in cartilage.

Budding or germination consists in the projection of a little process or bud from the mass of bioplasm, which is separated by the constriction of its base, and becomes an independent cell.

8. *Reproduction in the higher organisms* consists essentially of the production of two distinct elements, a germ-cell or ovum, and a sperm-cell or spermatozoid, by the contact of which the ovum is enabled to develop a new individual. Sometimes these elements are produced by different parts of the same organism, in which case the sexes are said to be united, and the individual is called hermaphrodite, androgynous, or monœcious. In other in-

plants the sexes are distinct, and the species are called dioecious.

9. *The alternation of generations* is a term given in biology to express a form of multiplication which occurs in some of the more simple forms of life. It consists really of the alternation of a true sexual generation with the phenomenon of budding. Thus a fern spore gives rise, by budding and cell-division, to a prothallium; this produces archegonia and antheridia, as the sexual elements are called, and the embryo which results from sexual union produces not a prothallium but a fern. This phenomenon is better seen in the *Hydrozoa*. In these the egg produces a minute, ciliated, free-swimming body, which attaches itself, becomes tapering, develops a mouth and tentacles, and is known as the *Hydra tuba*. This multiplies itself, and produces extensive colonies by germination, but under certain circumstances divides by fission and produces *Medusæ*, which develop ova.

10. *Parthenogenesis* designates the production of new individuals by virgin females without the intervention of a male. It has also been applied to germination and fission in sexless beings. In the *Aphides*, ova are hatched in spring, but ten or more generations are produced viviparously and without sexual union throughout the summer. In autumn, however, the final brood are winged males and wingless females, from whose union ova are produced in the ordinary manner.

11. *Transformation and metamorphosis* relate to certain changes or variations of development in the structure and life history of an individual. Thus an insect is an egg or *ovum*, a caterpillar or *larva*, a pupa or *chrysalis*, and an *imago* or perfect insect, and these changes of condition and structure constitute its development. Much difficulty is caused by the phenomena of metamorphosis in assigning the place of different species, transformations being often mistaken for specific differences. It was formerly

supposed that every animal passed through, in its development, a series of stages in which it resembled the inferior members of the animal scale, and systems of zoology were proposed to be founded on this dream of embryology. Careful research, however, has shown that larval changes present many variations. In some the young exhibit the conditions of adults of lower animals. Thus the *Eolis*, a univalve shell fish, in its young state has all the characteristics of a *Pteropod*, a free-swimming mollusk. Sometimes development is retrograde, and the adult is a degraded form as compared with the larva, thus setting at nought all our theories, and teaching us that it is better to observe than to imagine.

12. *Discrimination of Living Forms.*—We have seen, section 6, that there are different kinds of living matter endowed with different powers. We have also seen, section 7, how varied are the forms of multiplication. Yet when we come to discriminate between animal and vegetable life, we find it exceedingly difficult, especially in their more simple forms. Neither form, nor chemical composition, nor structure, nor motive power, affords sufficient grounds for discrimination. Yet when we consider the functions of bioplasm in its varied forms, we may conveniently group all living beings in three great divisions, viz., *fungi*, *plants*, and *animals*.

The bioplasm of the plant finds its pabulum in merely inorganic compounds, while that of the animal is prepared for it, directly or indirectly, by the vegetable. The function of fungi appears to be the decomposition of the formed material of plants and animals by the means of fermentation or putrefaction, since these latter processes are dependent on the presence of fungi. Thus by bioplasm are the structures of plants and animals reared from inorganic materials, and by bioplasm are they broken down and restored to the inanimate world.

CHAPTER X.

THE MICROSCOPE IN VEGETABLE HISTOLOGY AND BOTANY.

Histology (from ἱστος, a tissue) treats of formed material, or the microscopic structure resulting from the transformation of germinal or living matter. The nature of this transformation is partly physical and partly vital, and, as already stated, is often so complex as to baffle all chemical analysis. Some light, however, has been thrown on this subject by the modification of ordinary crystalline forms when inorganic particles aggregate in the presence of certain kinds of organic matter. To this mode of formation the name of *molecular coalescence* has been given. Mr. Rainey and Professor Harting contemporaneously experimented with solutions of organic colloids, and found that the crystallization of certain lime salts, as the carbonate, was so modified by such solutions as to resemble many of the calcareous deposits found in nature. These researches leave little doubt but that a majority of calcareous and silicious organic forms may be thus accounted for. Such changes are rather physical than vital.

Cell substance in Vegetables.—The protoplasm or bioplasm in vegetable-cells cannot be distinguished from animal "sarcode" or protoplasm except by the nature of the pabulum or aliment necessary to its nutrition. The vegetable, under the stimulus of light, decomposes carbonic acid, and acquires a red or green color from the compounds which it forms, while the animal requires nutriment from pre-existing organisms. Yet this definition fails to apply to fungi, which resemble primitive animals even in this respect. So difficult is it to discriminate that the simpler forms of vegetables have often been classed by naturalists among animals, and *vice versâ*. Amœboid movements have been observed in the bioplasm of vegetable-cells,

especially in the *Volvox*, and some have considered it probable that an organism may live a truly vegetable life at one period and a truly animal life at another.

Analogous to amœboid movements, is the motion of bioplasmic fluid in the interior of undoubtedly vegetable cells. This movement is called *cyclosis*, and may be detected under the microscope by the granules or particles which the current carries with it in the transparent cells of *Chara*, *Vallisneria*, etc., and in the epidermic hairs of many plants, as *Tradescantia*, *Plantago*, etc. (Plate VI, Fig. 91).

The bioplasm of plants may be stained with carmine solution without affecting the cell-wall or other formed material.

Cell-wall or Membrane.—Plants, whether simple or complicated in structure, are but cells or aggregations of cells. In the simplest vegetables or *Protophytes*, each cell lives as it were an independent life, performing every function; while in the higher plants, as the palm or oak, the cells undergo special modifications, and serve various functions subsidiary to the life of the plant as a whole.

Cell-membrane, or the envelope of formed material, was formerly thought to be composed of two layers, to the inner one of which the name of *primordial utricle* was given, but this is now considered to be but the external surface of the bioplasm or germinal matter.

The chemical nature of cell-membrane is nearly identical with starch, being composed of *cellulose*. The presence of cellulose may be shown by the blue color which is produced by applying iodine and sulphuric acid, or the iodized solution of chloride of zinc.

Endosmose will take place in cell-membrane, allowing solutions to pass through, as pabulum, and the manner of this passage may in some instances determine the subsequent deposit of formed material. Sometimes actual pores are left in the membrane, as in *Sphagnum* (Plate VI, Fig.

92). The walls of vegetable-cells are often thickened by deposit. If this is in isolated patches, the cells are called *dotted* (Plate VI, Fig. 93), and it is sometimes difficult to distinguish them from porous cells. Many cells have a spiral fibre (Plate VI, Fig. 94), which appears to have been detached from the outer membrane. In the seeds of *Collomia*, etc., the cell-wall is less consolidated than the deposit, so that on softening the cells by water, the spiral fibres suddenly spring out, making a beautiful object for a half-inch object-glass (Plate VI, Fig. 95).

The tendency of formed material to arrange itself in a spiral is seen in the endochrome of many of the simpler plants, as *Zygnema*, and the cell-wall sometimes tears most readily in a spiral direction.

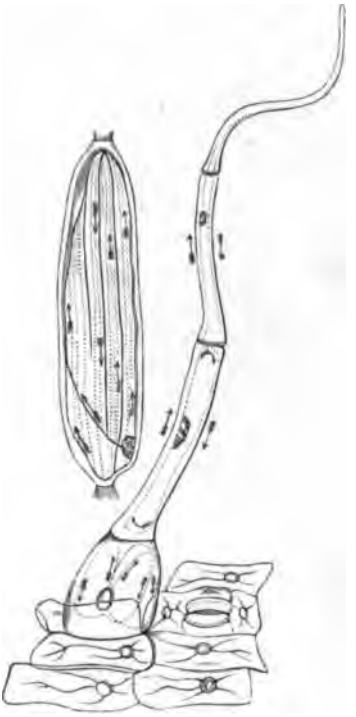
If the spiral deposit is broken and coalesces at some of its turns, it forms an annulus or ring. Some cells show both rings and spirals.

For the production of a spiral movement or growth, another force is needed in addition to the centripetal and centrifugal forces which are necessary for curvilinear motion. The centripetal point must be carried forward in space by a progressive force. When we consider that a spiral form is so frequently seen in morphology, that the secondary planets move in spirals round their primaries, and that even in distant nebulæ the same law prevails, we are struck with the unity of plan which is exhibited throughout the universe, and can scarcely fail to observe that even a microscopic cell shows the tracings of the same divine handiwork which swings the stars in their courses.

Sclerogen—Ligneous Tissue.—Sometimes the deposit within the cell-wall is of considerable thickness, and often in concentric rings, through which a series of passages is left so that the outer membrane is the only obstacle to the access of pabulum, as in the stones of fruit, gritty tissue of the pear, etc. (Plate VII, Fig. 96). The nature of this deposit is similar to cellulose, although often contain-

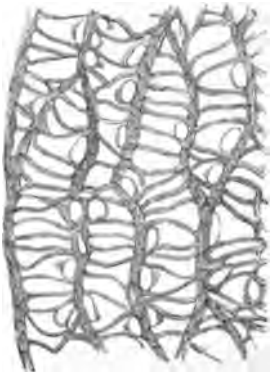
PLATE VI.

FIG. 91.



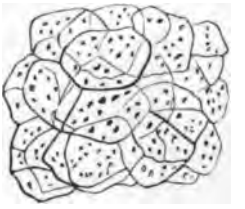
Circulation of fluid in hairs of *Tradescantia Virginica*.

FIG. 92.



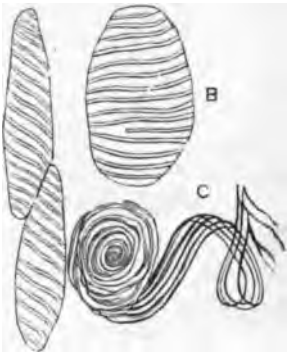
Portion of the leaf of *Sphagnum*.

FIG. 93.



Dotted cells—pith of Elder.

FIG. 94.



Spiral cells :—A, Balsam ; B, C, Pleurothallis.

FIG. 95.

Spiral fibres of seed-coat of *Collomia*.

ing resinous and other matters. Woody fibre or ligneous tissue is quite similar, save that the cells have become elongated or fusiform, and when completely filled up with internal deposit, fulfil no other purpose than that of mechanical support (Plate VII, Fig. 97). The woody fibres of the *Coniferæ* exhibit peculiar markings, which have been called *glandular* (Plate VII, Fig. 98). In these the inner circle represents a deficiency of deposit as in other porous cells, while the outer circle is the boundary of a lenticular cavity between the adjacent cells. This arrangement is so characteristic as to enable us to determine the tribe to which a minute fragment, even of fossil wood, belonged.

Spiral Vessels.—If spiral cells are elongated, or coalesce at their ends, they become vessels, some of which convey air and some fluid (Plate VII, Fig. 99). As in cells, the want of continuity in the spiral fibre sometimes produces rings, when the duct is called *annular*. In other instances the spires are still more broken up by the process of growth, so as to form an irregular network in the duct, which is then said to be *reticulated*. A still greater variation in the deposit produces *dotted ducts*. Not infrequently we find all forms in the same bundle of vessels.

Laticiferous Vessels (Plate VII, Fig. 100).—These convey the milky juice or *latex* of such plants as possess it, as the Euphorbiaceæ, india-rubber plant, etc., and differ from the ducts above described by their branching, so as to form a network, while ducts are straight and parallel with each other.

The laticiferous vessels resemble the capillary vessels of animals, while the spiral ducts remind us of the trachea of insects.

Siliceous Structures.—The structures of many plants, especially the epidermis, often become so permeated with a deposit of silica, that a complete skeleton is left after the soft vegetable matter is destroyed. The frustules of

Diatoms have in this way been preserved in vast numbers in the rocky strata of the earth. The markings on these siliceous shells are so delicate as to be employed as a test of microscopic power and definition. In a species of *Equisetum* or Dutch rush, silica exists in such abundance that the stems are sometimes employed by artisans as a substitute for sand-paper. If such a stem is boiled and macerated in nitric acid until all the softer parts are destroyed, a cast of pure silica will exhibit not only the forms of the epidermic cells, but details of the stomata or pores. The same also is true of the husk of a grain of wheat, etc., in which even the fibres of the spiral vessels are silicified. The stellate hairs of the siliceous cuticle from the leaf of *Deutzia scabra* forms a beautiful polariscope object.

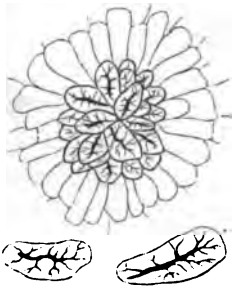
Formed Material within Vegetable Cells.

1. *Raphides.*—These are crystalline mineral substances, principally oxalate, citrate, and phosphate of lime. They occur in all parts of the plant, sometimes in the form of bundles of delicate needles, sometimes in larger crystals, and sometimes in stellate or conglomerate form. Mr. E. Quekett produced such forms artificially by filling the cells of rice-paper with lime-water under an air-pump, and then placing the paper in weak solutions of phosphoric or oxalic acid.

2. *Starch.*—This performs in plants a similar function to that of fat in animals, and is a most important ingredient in human food, since two-thirds of mankind subsist almost exclusively upon it. It is found in the cells of plants in the form of granules or secondary cells. Each granule under the microscope shows at one extremity a circular spot or *hilum*, around which are a number of curved lines, supposed to be wrinkles in the cell-membrane. When starch is boiled in water, this membrane bursts and

PLATE VII.

FIG. 96.

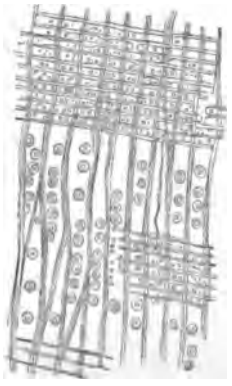


Gritty tissue—Pear.

FIG. 97.

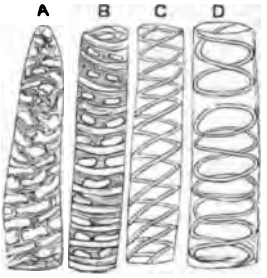
Wood-fibre—flax.

FIG. 98.



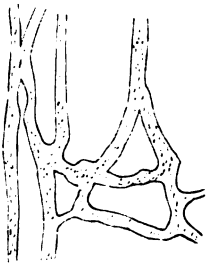
Section of *Coniferous Wood* in the direction of the fibres.

FIG. 99.



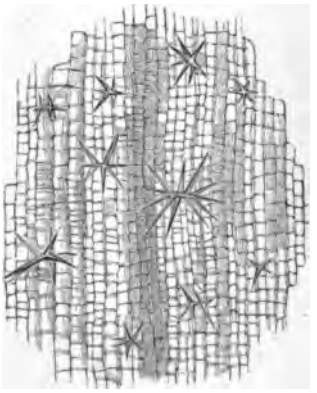
Spiral vessels:—A, reticulated; B, old vessel, with perforations; C, D, spiral vessels, becoming annular.

FIG. 100.



Lactiferous vessels.

FIG. 101.



Cubical parenchyma, with stellate cells, from petiole of *Nuphar lutea*.

the amylaceous matter is dissolved. Iodine stains starch blue. Starch shows in the polariscope a black cross in each grain, changing to white as the prism is revolved.

3. *Chlorophyll* is the green coloring matter of plants. It is usually seen in the form of granules of bioplasm in the interior of cells. These green granules yield their chlorophyll to alcohol and ether. It seems to be necessary to nutrition, since green plants under the stimulus of light break up carbonic acid into oxygen and carbon, the latter of which is absorbed.

The red and yellow color of autumn leaves is owing to the chemical metamorphosis of chlorophyll, as also is the red color of many of the lower Algæ, etc. In the latter it seems to be in some way connected with the vital processes.

4. *The coloring matter of flowers* is various, and ordinarily depends on the colored fluid contained in cells subjacent to the epidermis, although sometimes it is in the form of solid corpuscles. White patches on leaves, etc., arise from absence of chlorophyll.

5. *Milky juices* are true secretions contained in the laticiferous ducts. The juice of the dandelion, caoutchouc or india-rubber, which is the concrete juice of the *Ficus elastica*, and gutta-percha, from *Isonandra gutta*, are examples.

6. *Fixed oils* are found in the cells of active tissues, and notably in seeds, where they serve to nourish the embryo. Cocoanut, palm, castor, poppy, and linseed oils are examples.

7. *Volatile oil*, sometimes called essential oil, is chiefly found in glandular cells and hairs of the epidermis. Many of them yield a resinous substance by evaporation.

8. *Camphor* is analogous to volatile oil, although solid at ordinary temperatures. It abounds in the Lauraceæ.

9. *Resin*, *wax*, and *tallow* are also found in plants. The bloom of the plum and grape is due to wax.

10. *Gum* is a viscid secretion. What is called gum tragacanth, is said to be partially decomposed cell-membrane, and is allied to amyloid matter.

Forms of Vegetable Cells.—From the account given in the chapter on biology, page 123, it is evident that the form of cells is quite varied, and often depends on the amount of pressure from aggregation, yet function also has much to do in the determination of shape. Thus while most elongated cells are lengthened in the direction of plant-growth, in which is least resistance, the medullary rays of Exogenous stems are elongated in a horizontal direction. Some cells are cubical, as in the leaves of the yellow water-lily, *Nuphar lutea* (Plate VII, Fig. 101). Others are stellate, as in the rush (Plate VIII, Fig. 102). In many tissues are large cavities or air-chambers altogether void of cells, and in leaves such cavities communicate with the external air by means of *stomata* or pores (Plate VIII, Fig. 103), which are usually provided with peculiar cells for contracting or widening the orifice.

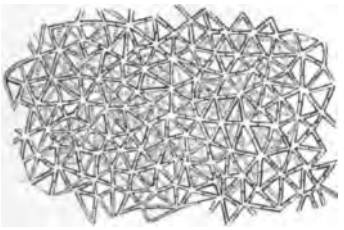
The Botanical Arrangement of Plants.—Considered with reference to their general structure, plants are divided by botanists into *cellular* and *vascular*. The first of these classes is of greatest interest to the microscopist, as embracing the minuter forms of vegetable life.

The classification and natural grouping of plants is yet far from being perfect, although microscopic examinations have largely contributed to an orderly arrangement of the multitudinous varieties in this field of research. In the present work we propose only a brief outline of typical subjects of interest, with the methods of microscopic examination.

Fungi.—At page 127 it was stated that all living beings may be grouped in three divisions, fungi, plants, and animals. Botanists generally class fungi among cellular flowerless plants. They cannot assimilate inorganic food as other plants, but live upon the substance of animal or

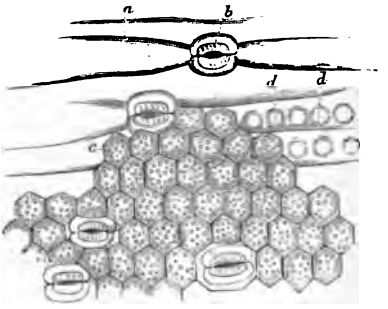
PLATE VIII.

FIG. 102.



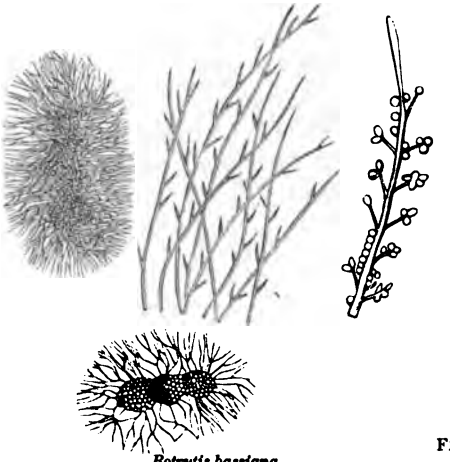
Section of cellular parenchyma of *Rush*.

FIG. 103.



Portion of the cuticle of the leaf of the *Iris Germanica*, torn from its surface.

FIG. 104.

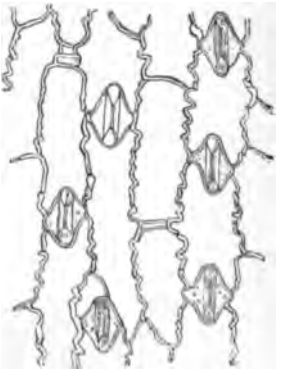


Botrytis bassiana.

FIG. 105.

Cells from the petal of the Geranium (*Pelargonium*).

FIG. 106.



Cuticle of leaf of Indian Corn (*Zea mais*).

vegetable tissue. They also differ from ordinary vegetables by the total absence of chlorophyll or its red modification. A large number of this strange class are microscopic, and require high powers for their observation. Recent investigations show that individual fungi are developed in very dissimilar modes, and are subject to a great variety of form, rendering it probable that those which seem most simple are but imperfectly developed forms. Amœboid motions also in the cell-substance of certain kinds of fungi, and the projection of threads of bioplasm, show a great resemblance to some of the lower forms of animal life, as the *Rhizopods*.

All fungi exhibit two well-defined structures, a *mycelium* or vegetative structure, which is a mass of delicate filaments or elongated cells: and a *fruit* or reproductive structure, which varies in different tribes. In *Torula*, one or more globular cells are produced at the ends of filaments composed of elongated cells; these globules drop off and become new mycelia. The "yeast plant," or *Torula cerevisiæ* (Plate IX. Fig. 107), receives its name from its habitat. Fermentation depends upon its presence, as putrefaction does upon the minute analogous bodies called *Bacteria* and *Vibriones*. Bacteria are minute, moving, rod-like bodies, sometimes jointed; and vibriones are moniliform filaments, having a vibratile or wriggling motion across the field of view in the microscope. The researches of Madame Luders render it probable that the germs of fungi develop themselves into these bodies when sown in water containing animal matter, and into yeast in a saccharine solution. The universal diffusion of sporules of fungi in the atmosphere readily accounts for their appearance in such fluids, and Pasteur's experiments are quite conclusive.

The minute molecules called *microzymes*, present in various products of disease, as the vaccine vesicle, fluid of glanders, etc.; the minute corpuscles which cause the dis-

ease among silkworms called "pebrine;" etc.; have a strong analogy in their rapid multiplication to the yeast-cells.

The sporules of any of the ordinary moulds, as *Penicillium*, *Mucor*, or *Aspergillus*, will develop into yeast-cells in a moderately warm solution of cane-sugar, showing how differently the same type of bioplasm may develop under different conditions. The term *polymorphism* has been given to this phenomenon. Very many species, and even genera, so called, may after all be only varieties of the same kind of organism.

In many morbid conditions of the skin and mucous membranes, there is not only an alteration or morbid growth of the part, but a vegetation of fungi. Thrown-off scales of epithelium from the mouth and fauces exhibit fibres of *leptothrix*, and the false membrane of diphtheria, as well as the white patches of aphtha or thrush, show the mycelia and spores of fungi. The disease in silkworms called muscardine is due to a fungus, the *Botrytis bassiana* (Plate VIII, Fig. 104), whose spores enter and develop in the air-tubes. The filamentous tufts seen about dead flies on window-panes, etc., arise from a similar growth of *Achyla*. In certain Chinese or Australian caterpillars, this sort of growth becomes so dense as to give them the appearance of dried twigs. Even shells and other hard tissues may become penetrated by fungi. The dry rot in timber is a form of fungus.

The mildew which attacks the straw of wheat, etc., arises from the *Puccinia graminis*, whose spores find their way through the stomata or breathing pores of the epidermis. *Rust*, and *smut*, and *bunt*, originate in varieties of *Uredo*. The "vine disease" and the "potato disease," as they are called, have similar origin.

Various methods have been proposed to destroy fungi in growing plants, but it must be remembered that the function of these organisms is chiefly to remove formed

PLATE IX.

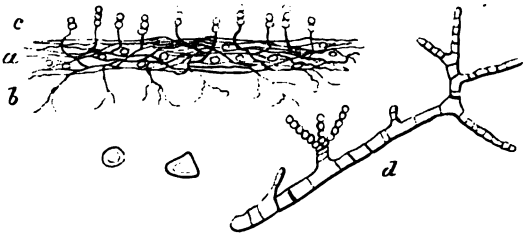
Fig. 107.

Torula Cerevisiæ, or Yeast-Plant.

Fig. 109.

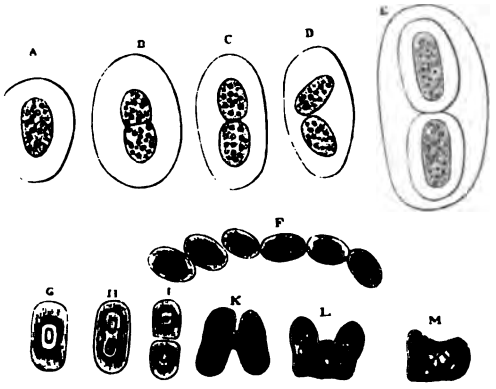
Germ and Sperm-cells in Achyla.

Fig. 108.



Development of fungi: A, mycelium; B, hypha; C, conidiophores; D, a magnified branch.

Fig. 110.



Various phases of development of *Palmoglæa macrococca*.

material in a state of decay, which is more or less complete. The prevalence of atmospheric changes, variations in light, heat, moisture, and electricity, etc., have much to do in predisposing vegetable as well as animal tissues to disease and producing epidemics. The agriculturist, therefore, as well as the physician, must discriminate between those diseased conditions which provide a habitat for fungi, and the effects produced by the fungi themselves.

Impregnating wood with corrosive sublimate or chloride of zinc has been used to prevent dry rot in wood, and soaking seeds in alkaline solutions or sulphate of copper is said to remove smut and similar fungus spores.

The development of fungi is from spores or *conidia*. Plate IX, Fig. 107, represents the Torula vegetating by the budding of its spores. These buds rapidly fall off and become independent cells. In other varieties self-division gives rise to the *mycelium*, a mass of fibres often interlaced so as to form a sort of felt. Some branches of this mycelium (*hyphæ*) hang down, while others rise above the surface (*conidiophores*) and bear conidia, which fall off and develop into new hyphæ (Plate IX, Fig. 108). In the "blight" of the potato the mycelium is loose, and the hyphæ ramify in the intercellular spaces and give off projections into the cells of the plant. The conidia germinate by bursting the sac which contains them, putting forth cilia, moving awhile, then resting and enveloping themselves with membrane and growing into hyphæ. In the autumn, parts of the hyphæ assume special functions. One part develops a spherical mass called *oogonium*, while another becomes a smaller mass or *antheridium*. When the first is ripe, it is penetrated by the latter, and the bioplasms of each are fused together. The antheridium then decays, while the oogonium grows and becomes an *oospore*, in which the bioplasm divides and subdivides. Next season each segment escapes ciliated, and moves about till it finds a place to germinate. In Achyla two

sacs are formed, one of which contains "germ-cells," and the other *antherozoids* or "sperm-cells." When both are ripe the sac opens, and the ciliated antherozoids pass into the neighboring sac and fertilize its contents (Plate IX, Fig. 109).

In other fungi the reproductive cells are undistinguishable from the rest, and the coalescence takes place in a new cell formed by the union of the other two.

Mr. Berkeley divides fungi into six orders, as follows:

1. *Hymenomycetes* or *Agaricoideæ* (*Mushrooms*, etc.).—Mycelium flocuose, inconspicuous, bearing fleshy fruits which expand so as to expose the hymenium or sporiferous membrane to the air. Spores generally in fours on short pedicles.

2. *Gasteromycetes* or *Lycoperdoideæ* (*Puff balls*, etc.).—Fruit globular or oval, with convolutions covered by the hymenium, which bears the spores in fours on distinct pedicles. The convolutions break up into a pulverulent or gelatinous mass.

3. *Coniomycetes* or *Uredoideæ* (*Smuts*, etc.).—Mycelium filamentous, parasitic. Microscopic fructification of sessile or stalked spores in groups, sometimes septate.

4. *Hyphomycetes* or *Botrytoideæ* (*Mildews*, etc.).—Microscopic. Mycelium filamentous, epiphytic, with erect filaments bearing terminal, free, single, simple, or septate spores.

5. *Ascomycetes* or *Helvelloideæ* (*Truffles*, etc.).—Mycelium inconspicuous. Fruit fleshy, leathery, horny, or gelatinous, lobed, or warty, with groups of elongated sacs (*asci* or *thecæ*) in which the spores (generally eight) are developed.

6. *Physomycetes* or *Mucoroideæ* (*Moulds*).—Mycelium (microscopic) filamentous, bearing stalked sacs containing numerous minute sporules.

Protophytes, or primitive plants, afford many forms and groups of great interest to the microscopist as well as to

the biologist. The plan of the present work permits us only to indicate a few particulars, the details of which would form a volume of considerable size.

The Algæ are divided into three orders: I. *Rhodospermeæ* or *Floridæ* (*Red-spored Algæ*). Marine plants, with a leaf-like or filamentous rose-red or purple thallus. II. *Melanosporeæ* or *Fucoideæ* (*Dark-spored Algæ*). Marine. Thallus leaf-like, shrubby, cord-like, or filamentous, of olive-green or brown color. III. *Chlorosporeæ* or *Confervoideæ* (*Green-spored Algæ*). Plants marine or fresh water, or growing on damp surfaces. Thallus filamentous, rarely leaf-like, pulverulent, or gelatinous. These have been subdivided into families, viz.:

I. *Rhodospermeæ*.—1. Rhodomelaceæ. 2. Laurenciaceæ. 3. Corallinaceæ. 4. Delesseriaceæ. 5. Rhodymeniaceæ. 6. Cryptonemiaceæ. 7. Ceramiaceæ. 8. Porphyraceæ.

II. *Melanosporeæ*.—1. Fucaceæ. 2. Dictyotaceæ. 3. Cutleriaceæ. 4. Laminariaceæ. 5. Dictyosiphonaceæ. 6. Punctariaceæ. 7. Sporochnaceæ. 8. Chordariaceæ. 9. Myrionemaceæ. 10. Ectocarpaceæ.

III. *Chlorosporeæ*.—1. Lemaneeæ. 2. Batrachospermeæ. 3. Chætophoraceæ. 4. Confervaceæ. 5. Zygnemaceæ. 6. Œdogoniaceæ. 7. Siphonaceæ. 8. Oscillatoriaceæ. 9. Nostochaceæ. 10. Ulvaceæ. 11. Palmellaceæ. 12. Desmidiaceæ. 13. Diatomaceæ. 14. Volvocineæ.

For fuller information, we refer to the *Micrographic Dictionary* by Griffith and Henfrey.

In the family of *Palmellaceæ* we find the simplest forms of vegetation in the form of a powdery layer of cells, or a slimy film, or a membranous frond. The green mould on damp walls and the red snow of alpine regions are examples.

In the green slime on damp stones, etc., is found the *Palmoglœa macrococca*. The microscope shows it to consist of cells containing chlorophyll, surrounded by a gelatinous envelope. These cells multiply by self-division.

Sometimes a conjugation or fusion of cells occurs, and the product is a *spore* or primordial cell of a new generation (Plate IX, Fig. 110). During conjugation oil is produced in the cells, and the chlorophyll disappears or becomes brown, and when the spore vegetates, the oil disappears and green granular matter takes its place. This is analogous to the transformation of starch into oil in the seeds of the higher plants.

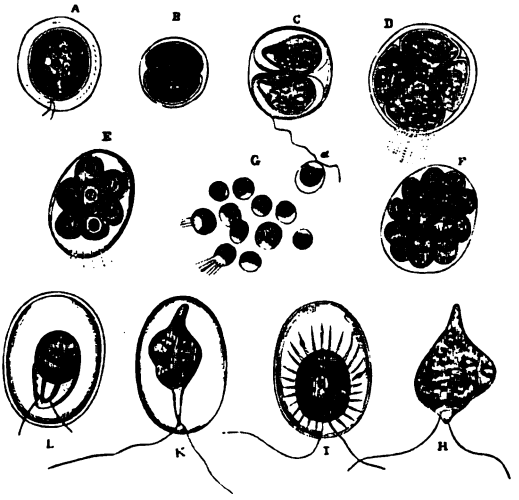
Most of the lower forms of vegetable life pass through what is called the motile condition, which depends on the extension of the bioplasm into thread-like filaments, whose contractions serve to move the cell through the water. Many of these forms were formerly mistaken for animalcules, and the transformation of a portion of green chlorophyll into the red form was represented as an eye. The multiplication of the "still" cells is by self-division, as in *Palmoglea*, but after this has been repeated about four times, the new cells become furnished with cilia and pass into the "motile" condition, and their multiplication goes on in different ways, as by binary or quaternary segmentation, or the formation of a compound, mulberry-like mass, the ciliated individual cells of which, becoming free, rank as *zoospores* (Plate X, Fig. 111).

The *Volvox* is a beautiful example of the composite motile form of elementary vegetation. It is found in fresh water, and consists of a hollow pellucid sphere, studded with green spots, connected together often by green threads. Each of these spots has two cilia, whose motions produce a rolling movement of the entire mass. Within the sphere there are usually from two to twenty smaller globes, which are set free by the bursting of the original envelope. Sometimes one of the masses of endochrome enlarges, but instead of undergoing subdivision becomes a moving mass of bioplasm, which cannot be distinguished from a true *Amœba* or primitive animal cell.

The *Desmidiaceæ* are a family of minute green plants

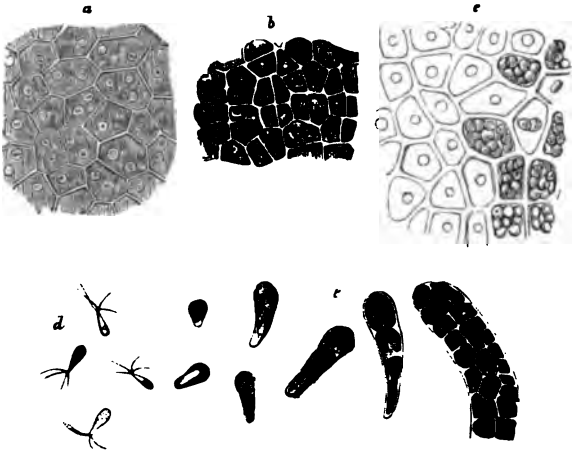
PLATE X.

FIG. 111.



Various phases of development of *Protococcus pluvialis*.

FIG. 112.



Formation of Zoospores in *Phycoseris gigantea* (Ulva latissima).

of great interest. Generally the cells are independent, but a filament is sometimes formed by binary subdivision. Their symmetrical shape, and frequently spinous projections and peculiar movements, render them beautiful objects. By conjugation a spore-cell or *sporangium* is produced, which in some species is spinous, and resembles certain fossil remains in flint, which have been described as animalcules under the name of *Xanthidia*.

The family of *Diatomaceæ* affords more occupation to microscopists than other protophytes. Like the *Desmids*, they are simple cells with a firm external coating, but in Diatoms this coating is so penetrated with silex, that a cast of the frustule is left after the removal of the organic matter. Reference has already been made to the number of these organisms in a fossil state, as well as to their utility as tests of the defining power of microscopic object-glasses.

Some species inhabit the sea, and others fresh water. They are so numerous that scarcely a ditch or cistern is free from specimens, and they multiply so rapidly as to actually diminish the depth of channels and block up harbors. They may be sought for in the slimy masses attached to rocks and plants in water, in the scum of the surface, in mud or sand, in guano, in the stomachs of molluscs, etc., and on sea-weeds.

To separate the shields or siliceous frustules from foreign matter, either fresh or fossil, they should be washed several times in water, and the sediment allowed to subside. The deposit should then be treated in a test-tube with hydrochloric acid, sometimes aided by heat. This should be repeated as often as any effect is produced, and then the sediment should be boiled in strong nitric acid, and washed several times in water. They may be mounted dry or in balsam.

The classification of Diatoms is not yet perfected, but Muller's type slides, containing from one hundred to five

hundred characteristic forms, is a valuable assistance. The following table, from the *Micrographic Dictionary*, gives an analysis of tribes and genera: Fr. denotes the frustules in front view; v. the valves; granular striæ means striæ resolvable into dots; and continuous striæ signify costæ or canaliculæ.

A. *Frustules not contained in a Gelatinous Mass or Tube.*

TRIBE I. STRIATÆ.—Frustules usually transversely striate, but neither vittate nor areolate.

† *Valves without a Median Nodule.*

COHORT 1. EUNOTIEÆ.—Fr. arcuate, single, or united into a straight filament.

1. *Epithemia.*—Fr. single or binate, with transverse or slightly radiant striæ, some continuous; no terminal nodules; aquatic and marine.

2. *Eunotia.*—Fr. single or binate; v. with slightly radiant granular striæ and terminal nodules; aquatic.

3. *Himantidium.*—Fr. as in *Eunotia*, but united into a filament; striæ parallel, transverse; aquatic.

COHORT 2. MERIDEÆ.—Fr. cuneate, single, or united into a curved or spinal band; v. with continuous or granular striæ.

4. *Meridion.*—Fr. cuneate, united into a spiral band; striæ continuous; aquatic.

5. *Eucampia.*—Fr. united into an arched band; v. punctate; marine.

6. *Oncosphenia.*—Fr. single, cuneate, uncinate at the narrow end; striæ granular; aquatic.

COHORT 3. FRAGILLARIEÆ.—Fr. quadrilateral, single, or united into a filament or chain; v. with continuous or granular striæ.

7. *Diatoma.*—Fr. linear or rectangular, united by the

angles so as to form a zigzag chain; striæ continuous; aquatic and marine.

8. *Asterionella.*—Fr. adherent by adjacent angles into a star-like filament; v. inflated at one or both ends; aquatic.

9. *Fragillaria.*—Fr. linear, united into a straight, close filament; striæ granular, faint; aquatic and marine.

10. *Denticula.*—Fr. linear, simple, or binate, rarely more united; striæ continuous; aquatic.

11. *Odontidium.*—As *Denticula*, but fr. forming a close filament; aquatic and marine.

Cohort 4. Melosireæ.—Fr. cylindrical, disk-shaped or globose; v. punctate, or often with radiate continuous or granular striæ.

12. *Cyclotella.*—Fr. disk-shaped, mostly solitary; v. with radiate marginal striæ; aquatic.

13. *Melosira.*—Fr. cylindrical or spherical, united into a filament; v. punctate, or with marginal radiate granular striæ; aquatic and marine.

14. *Podosira.*—Fr. united in small numbers, cylindrical or spherical, fixed by a terminal stalk; v. hemispherical, punctate; marine.

15. *Mastogonia.*—Fr. single; v. unequal, angular, mammiform, circular at base, without umbilical processes; angles radiating; fossil.

16. *Pododiscus.*—Fr. single or united, with a marginal stalk; v. circular, convex.

17. *Pyxidicula.*—Fr. single or binate, free or sessile; v. convex; aquatic and marine.

18. *Stephanodiscus.*—Fr. single, disk-shaped; v. circular, equal, punctate, or striate, with a fringe of minute marginal teeth; aquatic.

19. *Stephanogonia.*—Fr. as in *Mastogonia*, but ends of valves truncate, angular, and spinous; fossil.

20. *Hercotheca.*—Fr. single, turgid laterally; v. with marginal free setæ.

21. *Conicotheca.*—Fr. single, constricted in the middle, suddenly attenuate and truncate at the ends (hence appearing angular).

Cohort 5. SURIRELLEÆ.—Fr. single or binate, quadrilateral, oval, or saddle-shaped, sometimes constricted in the middle; v. with transverse or radiating continuous or granular striæ, interrupted in the middle, or with one or more longitudinal rows of puncta; often keeled.

22. *Bacillaria.*—Fr. prismatic, straight, at first forming a filament; v. with a median longitudinal row of puncta; marine.

23. *Campylodiscus.*—Fr. single, free, disk-shaped; v. curved or twisted (saddle-shaped); aquatic and marine.

24. *Doryphora.*—Fr. single, stalked; v. lanceolate or elliptical, with transverse granular striæ.

25. *Eulocystis.*—Fr. attached, sessile; v. with a median line, transverse continuous, and intermediate granular striæ.

26. *Nitzschia.*—Fr. free, single, compressed, usually elongate, straight, curved, or sigmoid, with a not-median keel, and one or more longitudinal rows of puncta; aquatic and marine.

27. *Sphinctocystis* (*Cymatopleura*).—Fr. free, single, linear, with undulate margins; v. oblong or elliptical, sometimes constricted in the middle; aquatic.

28. *Surirella.*—Fr. free, single, ovate, elliptical, oblong, cuneate, or broadly linear; v. with a longitudinal median line or clear space, margins winged, and with transverse or slightly radiating continuous striæ; aquatic and marine.

29. *Synedra.*—Fr. prismatic, rectangular, or curved; at first attached to a gelatinous-lobed cushion, often becoming free; v. linear or lanceolate, usually with a median pseudo-nodule and longitudinal line; aquatic and marine.

30. *Tryblionella.*—Fr. free, linear, or elliptical; v. plane, with a median line, transverse striæ, and submarginal or obsolete alæ; aquatic and marine.

31. *Raphoneis.*—*Doryphora* without a stalk.

COHORT 6. AMPHIPLEUREÆ.—Fr. free, single, straight, or slightly sigmoid; v. lanceolate, or linear-lanceolate, with a median longitudinal line.

32. *Amphipleura.*—Characters as above.

†† *Valves with a Median Nodule.*

COHORT 7. COCCONEIDÆ.—Fr. straight or bent, attached by the end or side; v. elliptical, equilateral.

33. *Cocconeis.*—Fr. single, compressed, adnate; v. elliptical, one of them with a median line.

COHORT 8. ACHNANTHEÆ.—Fr. compressed, single, or rarely united into a straight filament, curved, attached by a stalk at one angle; uppermost v. with a longitudinal median line, lower v. the same, and a stauros or transverse line; marine.

35. *Achnanthidium.*—Fr. those of *Achnanthes*, but free; aquatic.

36. *Cymbosira.*—Fr. as *Achnanthes*, solitary or binate, stipitate, and attached end to end; marine.

COHORT 9. CYMBELLEÆ.—Fr. straight or curved, free or stalked at the end; v. inequilateral, not sigmoid.

37. *Cymbella.*—Fr. free, solitary; v. navicular, with a subcentral and two terminal nodules, and a submedian longitudinal line; aquatic.

38. *Cocconema.*—Fr. as *Cymbella*, but stalked; aquatic.

COHORT 10. GOMPHONEMEÆ.—Fr. wedge-shaped, straight, free, or stalked; v. equilateral.

39. *Gomphonema.*—Fr. single or binate, wedge-shaped, attached by their ends to a stalk; v. with a median line, and a median and terminal nodules; aquatic.

40. *Sphenella.*—Fr. free, solitary, wedge-shaped, involute; aquatic.

41. *Sphenosira.*—Fr. united into a straight filament; v. wedge-shaped, at one end rounded, suddenly contracted and produced; aquatic.

Cohort 11. Naviculeæ.—Fr. free, straight; v. equilateral, or sometimes sigmoid.

42. *Navicula.*—Fr single, free, straight; v. oblong, lanceolate, or elliptical, with a median line, a central and two terminal nodules, and transversely or slightly radiant lines resolvable into dots; aquatic, marine, and fossil.

43. *Gyrosigma* (*Pleurosigma*).—Fr. as *Navicula*, but v. sigmoid; aquatic and marine.

44. *Donkinia*.—Fr as *Navicula*, but transverse lines continuous; aquatic and marine.

45. *Stauroneis*.—Fr. as *Navicula*, but the median line replaced by a stauros; aquatic and marine.

46. *Colletonema*.—Fr as *Navicula*, united into a straight filament; aquatic

47. *Amphiprora*.—Fr. free, solitary, or in pairs, constricted in the middle; v. with a median keel, and a median and terminal nodules, often twisted; marine.

48. *Cymbella*.—Fr. plano-convex, elliptical, oval or oblong, solitary, free or adnate, with a marginal line, and a nodule or stauros on the flat side; aquatic and marine.

Tribe II. Virgatæ.—Fr. with virgæ.

I. Valves without a Median Nodule.

Cohort 12. Tabellarieæ.—Fr. cuneate; virgæ arched.

49. *Tabellaria*.—Fr. cuneate, rounded at the broad end, radiating from a branched stalk; virgæ curved by inflection of upper margins of valves; marine.

50. *Meloseira*.—Fr. as *Tabellaria*, but single or in pairs, sessile on a thick but little branched pedicle; marine.

51. *Rhipidophora.*—Fr. as *Licmophora*, single or in pairs, on a branched stipes; marine.

52. *Climacosphenia.*—Fr. cuneate, rounded at broad end, divided into loculi by transverse septæ or vittæ; marine.

Cohort 13. Striatelleæ.—Fr. tabular or filamentous; vittæ straight (not arched).

53. *Striatella.*—Fr. compound, stalked at one angle; vittæ longitudinal and continuous; v. elliptic-lanceolate, not striated; marine.

54. *Rhabdonema.*—Fr. as *Striatella*, but vittæ interrupted; v. with transverse granular striæ; marine.

55. *Tetracyclus.*—Fr. compound, filamentous; vittæ alternate, interrupted; v. inflated at the middle; striæ transverse, continuous; aquatic.

56. *Tabellaria.*—Fr. united into a filament, subsequently breaking up into a zigzag chain; vittæ interrupted, alternate; v. inflated at middle and ends; aquatic.

57. *Pleurodesmium.*—Fr. tabular, united into a filament, and with a transverse median hyaline band; marine.

58. *Hyalosira.*—Fr. tabular, fixed by a stalk at one angle; vittæ alternate, interrupted, bifurcate at the end; marine.

59. *Anaulus.*—Fr. rectangular, single, compressed, with lateral inflections, giving the valves a ladder-like appearance; marine.

60. *Biblarium.*—Fr. as *Tetracyclus*, but single; fossil.

61. *Terpsinoë.*—Fr. tabular, obsoletely stalked, subsequently connected by isthmi; vittæ transverse, short, interrupted, and capitate; aquatic and marine.

62. *Stylobiblium.*—Fr. compound; v. circular, sculptured with continuous striæ; fossil.

†† *With a Median apparent (pseudo) Nodule.*

63. *Grammatophora.*—Fr. at first adnate, afterwards

forming a zigzag chain; vittæ two, longitudinal, interrupted, and more or less figured; marine.

TRIBE III. AREOLATÆ.—Valves circular, with cell-like (areolar) markings, visible by ordinary illumination.

SUB-TRIBE 1. DISCIFORMES.—Valves alike, without appendages or processes.

COHORT 14. COSCINODISCEÆ.—Valves circular.

64. *Actinocyclus.*—Fr. solitary; v. circular, undulate, the raised portions like rays or bands radiating from the centre, which is free from markings; marine and fossil.

65. *Actinoptychus.*—Fr. as *Actinocyclus*, but radiating internal septæ, as well as rays.

66. *Coscinodiscus.*—Fr. single; v. circular, areolar all over; marine and fossil.

67. *Arachnoidiscus.*—Fr. single; v. circular, not undulate, with concentric and radiating lines, and intermediate areola absent from the centre (pseudo-nodule); marine and fossil.

68. *Asterolampra.*—Fr. single; v. circular, finely areolar, except in the centre and at equidistant clear marginal rays radiating from the centre, which is traversed by radiating dark lines (septa), alternating with the marginal rays; fossil.

69. *Asteromphalos.*—As *Asterolampra*, but two of the central dark lines parallel, and the corresponding marginal ray obliterated; fossil.

70. *Halionyx.*—Fr. single; v. circular, without septa, with rays not reaching the centre, and with intermediate shorter rays; between the rays transverse areolar lines; fossil.

71. *Odontodiscus.*—Fr. single, lenticular; v. covered with puncta (areolæ), arranged in radiating rows on excentrically curved lines, and with erect marginal teeth; fossil.

72. *Omphalopelta.*—As *Actinoptychus*, but upper part of margin of valves with a few erect spines; fossil.

73. *Symbolophora.*—Fr. single, disk-shaped; v. with incomplete septa radiating from the solid angular umbilicus, and intermediate bundles of radiating lines; marine and fossil.

74. *Systephania.*—Fr. single; v. circular, areolar, without rays or septa, with a crown of spines or an erect membrane on the outer surface of each valve; fossil.

Cohort 15. Angulifera.—Valves angular.

75. *Amphitetras.*—Fr. at first united, afterwards separating into a zigzag chain, rectangular; v. rectangular, the angles often produced; marine.

76. *Amphipentras.*—Fr. solitary; v. pentangular; fossil.

77. *Lithodesmium.*—Fr. united into a straight filament; v. triangular, one side plane, the others undulate; marine.

Tribe IV. Appendiculatæ.—Valves with processes or appendages, or with the angles produced or inflated.

Cohort 16. Eupodisceæ.—Fr. disk-shaped; v. circular.

78. *Eupodiscus.*—Fr. single, disk-shaped; v. circular, with tubular or horn-like processes on the surface; aquatic and marine.

79. *Auliscus.*—As *Eupodiscus*, but processes obtuse and more solid; fossil.

80. *Insilella.*—Fr. single, fusiform; v. equal, with a median turgid ring between them; marine.

Cohort 17. Biddulphieæ.—Fr. flattened; v. elliptical or suborbicular.

81. *Biddulphia.*—Fr. rectangular, more or less united into a continuous or zigzag filament; the angles inflated or produced into horns; v. convex, centre usually spinous; marine.

82. *Isthmia.*—Fr. rhomboidal or trapezoidal, cohering by one angle; angles produced; marine.

83. *Chætoceros.*—Fr. compressed; v. equal, with a long spine or filament on each side; marine.

97. *Encyonema.*—Frond filamentous, but little branched; fr. like *Cymbella;* aquatic.

98. *Syncyclia.*—Fr. those of *Cymbella*, united in circular bands, immersed in an amorphous gelatinous frond; marine.

99. *Frustulia.*—Fr. as *Navicula*, irregularly scattered through an amorphous gelatinous mass; aquatic.

100. *Micromega.*—Fr. as *Navicula*, arranged in rows in gelatinous tubes, or surrounded by fibres, these being inclosed in a filiform branched frond; marine.

The family of *Nostochinæ* is allied to the *Palmellaceæ*. It consists of beaded filaments suspended in a gelatinous frond. The gelatinous masses of *Nostoc* often appear quite suddenly in damp places, and have been called "fallen stars." They attracted the notice of the alchemists, and enter into many of their recipes for the transmutation of metals. What have been termed showers of flesh or of blood, originated in all probability in the rapid development of similar masses. Many botanists regard them as the "gonidia" of *Collema* and other lichens.

The *Oscillatoria*, so called from the singular oscillatory motion of their filaments, consist also of cells which multiply in a longitudinal direction by self-division. The *Ulvaceæ*, to which the grass-green sea-weeds belong, increase in breadth as well as length by the subdivision of cells, so as to produce a leaf-like expansion (Plate X, Fig. 112). An illustration of the simpler forms of reproduction in Protophytes is seen in *Zygnema*, so called from the singular manner in which the filaments are yoked together in pairs. In an early stage of growth, while multiplication of cells proceeds by subdivision, the endochrome is generally diffused, but about the time of conjugation it arranges itself usually into a spiral. Adjacent cells put forth protuberances, which unite and form a free passage between them, and the endochrome of one cell passes over

into the other and forms the spore. In *Sphæroplea* the endochrome of the "oospore" breaks up into segments, which escape as "microgonidia." Each of these have two vibratile filaments, which elongate so as to become fusiform, and at the same time change from red to green. Losing their motile power they become filaments, in which the endochrome, by the multiplication of vacuoles, becomes frothy. After a time the particles of endochrome assume a globular or ovoid shape, and openings occur in the cell-wall. In other filaments the endochrome is converted into antherozoids, each of which is furnished with two filaments, by means of which they swim about and enter the openings of the spore-cells, in which they seem to dissolve away. The contents of the spore-cell then becomes invested with a membranous envelope; the color changes from green to red; a second investment is formed within the first, which extends itself into stellate projections. When set free the mass is a true oospore, and ready to repeat the process above described. In *Œdogonium* the antherozoids are developed in a body called an "androspore," which is set free from a germ-cell, and which being furnished with cilia resembles an ordinary zoospore. This androspore attaches itself to the outer surface of a germ-cell, a sort of lid drops from its free extremity, which sets free its contained antherozoids. These enter an aperture formed in the cell-wall of the oospore, and fertilize the contained mass by blending with it.

Examination of the Higher Cryptogamia.—It would enlarge this volume far beyond its proposed limits to refer to the particular instances of form or function which the microscope reveals to the systematic botanist or physiologist, nor is this necessary, since well-written treatises on structural botany are quite available. We content ourselves, therefore, in the remainder of this chapter, with pointing out the methods of examination by which the

views of other observers may be verified, or additions made to our knowledge of vegetable life.

The lower forms of algæ and fungi, to which we have already referred, need scarcely any preparation, save the disentanglement of twisted threads under the simple microscope, or a gentle teasing with needles, or rinsing with water. The solution of iodine, and of iodine and sulphuric acid, will suffice to exhibit the nature of the cell-wall and cell-contents. In more highly developed plants it will be necessary to take thin sections from different parts, and in different but definite directions. These sections may be made by hand, or between pieces of pith or cork by means of a section cutter. In some instances some of the methods of staining will also be useful. Dr. Hunt, of Philadelphia, has proposed a plan of staining which is well adapted to all vegetable tissues. He first soaks the part or section in strong alcohol to dissolve the chlorophyll, then bleaches it in a solution of chlorinated soda. It is then placed in a solution of alum, and afterwards in one of extract of logwood. By transferring it to weak alcohol and afterwards to stronger, it is deprived of its water, and after being made transparent with oil of cloves, it is ready for mounting in balsam or dammar varnish. Care must be taken to wash it well after each of the preliminary steps before staining.

In the higher algæ, the layers of cells assume various sizes and shapes, and the nature of their fructification is of great interest. Sections may be made of the "receptacles" at the extremities of the fronds, which contain filaments, whose contents become antherozoids. The pear-shaped sporangia in the receptacles subdivide into clusters of eight cells, called octospores, which are liberated from their envelopes before fertilization.

The red sea-weeds, or *Rhodospermeæ*, afford many beautiful forms for the microscope. The "tetraspores" are imbedded in the fronds.

In *lichens*, the *apothecia* form projections from the thallus, or general expansion produced by cell-division. A vertical section shows them to contain *asci* or spore-cases amid straight filaments, or elongated cells called *paraphyses*.

The fronds of *Hepaticæ* or liverworts bear stalks with shield-like disks, which carry antheridia, and others with radiating bodies bearing archegonia, which afterwards give place to the sporangia or spore-cases. The spores are associated with *elaters*, or elastic spiral fibres, which suddenly extend themselves and disperse the spores.

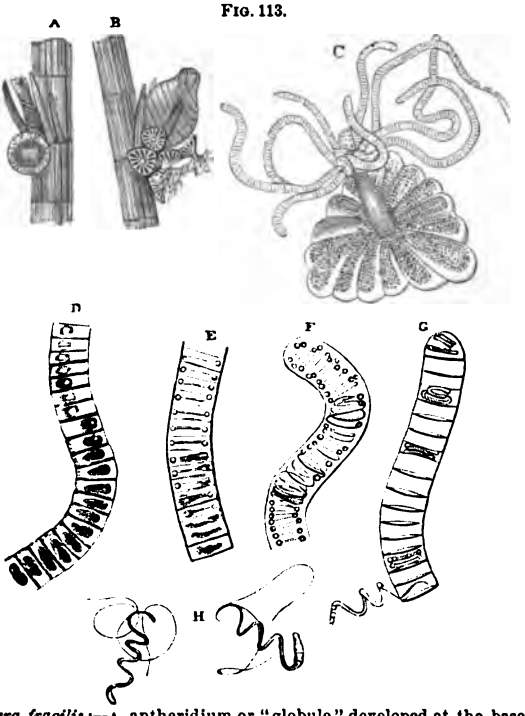
The *Characeæ* are often incrusted with carbonate of lime, which may be removed with dilute sulphuric acid. The motion of the bioplasm in the cells of the stem is often well seen. The cells in which the spiral filaments or antheridia are developed, are strung together like a row of pearls. The position and construction of the spores also should be examined, as well as the mode of growth in the plant by division of the terminal cell (Plate XI, Fig. 113).

Stems of *mosses* and liverworts should be examined by means of transverse and longitudinal sections. Similar sections through the half-ripe fruit of a moss will show the construction of the fruit, the peristome, the calyptra, etc. The ripe spores may be variously examined dry, in water, in oil of lemons, and in strong sulphuric acid. The capsules or urns of mosses are not now regarded as their fructification, but its product.

The true *antheridia* and *pistillidia* are found among the bases of the leaves, close to the axis. The fertilized "embryo-cell" becomes gradually developed by cell-division into a conical body or spore-capsule, elevated on a stalk. The *peristome*, or toothed fringe, seen around the mouth of the urn when the *calyptra* or hood, and *operculum* or lid, are removed, furnishes a beautiful object for the binocular microscope.

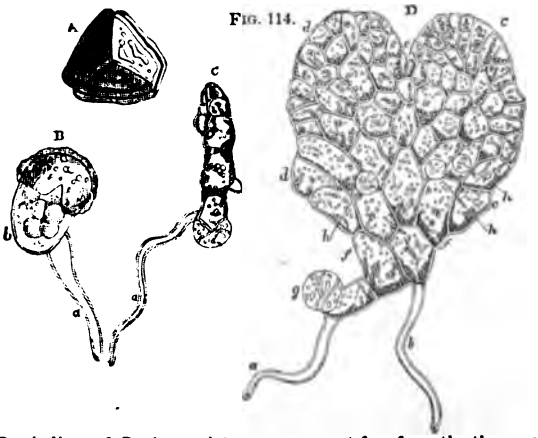
PLATE XI.

FIG. 113.



Antheridia of *Chara fragilis*:—A, antheridium or "globule" developed at the base of pistillidium or "nucule;" B, nucule enlarged, globule laid open by the separation of its valves; C, one of the valves, with its group of antheridial filaments, each composed of a linear series of cells, within every one of which an antherozoid is formed; in D, E, and F, the successive stages of this formation are seen; and at G is shown the escape of the mature antherozoids, H. (From Carpenter.)

FIG. 114.



Development of Prothallium of *Pteris serrulata*:—A, spore set free from the theca; B, spore beginning to germinate, putting forth the tubular prolongation *a*, from the principal cell *b*; C, first formed linear series of cells; D, prothallium taking the form of a leaf-like expansion; *a* first and *b* second radical fibre; *c*, *d*, the two lobes, and *e* the indentation between them; *f*, *f*, first-formed part of the prothallium; *g*, external coat of the original spore; *h*, *h*, antheridia. (From Carpenter.)

The *Sphagnum*, or bog-moss, has large and elongated leaf-cells, with loosely-coiled spiral fibres, and their membranous walls have large apertures. Their spores are of two kinds, and when germinating in water, produce a long filament with root-fibres at the lower end and a nodule at the upper, from which the young plant is formed. If grown on wet peat, instead of a filament there is evolved a lobed foliaceous *prothallium*, resembling the frond of liverworts.

In *ferns* the structure approximates to true flowering plants, while the reproductive organs are those of cryptogamia. Thin sections of the stem, cut obliquely, show the scalariform or ladder-like vessels. The fructification is usually found on the under side of the frond in isolated spots called *sori*. Each of these contains a number of capsules or *thecæ*, and each capsule is surrounded by an *annulus* or ring, whose elasticity opens the capsule when ripe and permits the spores to escape. The spores are somewhat angular, and when vegetating give rise to a leaf-like expansion called a *prothallium*. In this the *antheridia* and *archegonia*, which represent the true flower of higher plants, are developed. The ciliated antherozoids from the antheridia penetrate the cavity of the archegonium and fertilize the "germ-cell," which subdivides and becomes a young fern, while the prothallium, having discharged the functions of a nurse, withers away (Plate XI, Fig. 114). The group of *Equisetaceæ* or horsetails is interesting from the siliceous skeletons of the epidermis, already referred to, page 131, as well as for the elastic filaments attached to their spores.

Examination of Higher Plants.

The elementary tissues described in the beginning of this chapter are chiefly characteristic of phanerogamic plants, yet some additional particulars remain to be no-

ticed in connection with the axis or stem, the leaves, flowers, and fruit.

1. *The Stem.*—The arrangement of fibro-vascular bundles, *i. e.*, woody fibres and ducts, differs widely in the two botanical divisions of *Monocotyledons* and *Dicotyledons*. In the first the growth is *endogenous*, and a section exhibits the bundles of fibres and ducts disposed without regularity in the mass of cellular tissue which forms the basis of the fabric. In the second, or *exogenous* stems, the fibro-vascular bundles are wedge-shaped, and interposed between the bark and the pith, being kept apart by plates of cellular tissue, called medullary rays, proceeding from the pith.

The course of the vascular bundles in monocotyledons should be carefully followed, either by maceration or minute dissection. In the dicotyledonous stem, sections must be made in three directions, transversely, longitudinally across the diameter, and at a tangent from the bundles of fibres. The section-cutter, described page 63, will be serviceable, although a sharp razor or scalpel may serve. The size, form, and contents of the pith-cells should be noticed, and their transition to wood-cells. The arrangement of the medullary rays, of the wood-cells, and of the ducts must also be observed, and in the Coniferæ the position of the pits. The cambium layer, between the bark and wood, may have its cells rendered more transparent by weak alkalies, and their contents tested with iodine solution. The course and construction of latticiferous vessels in the bark, when present, and of the cork cells of the tuberous layer, may be noted.

Small woods may be cut with a watch-spring saw, and ground on a hone like bone or teeth. Sometimes it is best to break off small lamella by careful strokes with a steel hammer. It is sometimes useful to digest fossil wood in a solution of carbonate of soda for several days before cutting.

2. *Leaves.*—These should be examined by thin longitudinal and transverse sections. The epidermis of both sides should be detached, and the position and arrangement of the stomata observed (Plate VII, Fig. 100). The hairs of the epidermis, the arrangement of the parenchyma, and the distribution of the vascular bundles in the form of nerves, are also of importance.

3. *Flowers.*—For ascertaining the number and position of the parts of the flower, transverse sections at different heights through an unopened bud may be taken, together with a longitudinal section exactly through the middle. The general structure of sepals and petals corresponds with that of leaves, but there are some peculiarities. Thus the cells of the petal of the geranium exhibit when deprived of epidermis, dried and mounted in balsam, a peculiar mammillated appearance with radiating hairs (Plate VIII, Fig. 102). Anthers and pollen grains are also interesting microscopic objects. The protrusion of the inner membrane through the exterior pores in pollen may be stimulated by moistening with water, dilute acid, etc. The penetration of the pollen tubes through the tissue of the style may be traced by sections or careful dissection. The heartsease, *viola tricolor*, and the black and red currant, *ribes nigrum* and *rubrum*, have been recommended for this purpose.

4. *Seeds.*—The reticulations or markings on various kinds of seeds render them frequent objects for observation with the binocular microscope. Adulterations may also be detected in this way, as well as imperfect seeds in any sample, a subject of much importance to the practical farmer.

CHAPTER XI.

THE MICROSCOPE IN ZOOLOGY.

We have already seen that both animal and vegetable structures originate in a jelly-like mass or cell, and that in the simple forms it is difficult, if not impossible, to determine whether the object is an animal or a vegetable. The mode of alimentation, and not structure, is our only guide in the discrimination of the *Protozoa* or elementary animal forms from *Protophytes* or simple vegetables.

It has been proposed by Professor Hæckel to revive the idea of a kingdom of nature intermediate between plants and animals, but it does not appear that any gain to science would result from such an arrangement.

I. Monera.—The simplest types of *Protozoa* are mere particles of living jelly (Plate XII, Fig. 115), yet they possess the power of contraction and extension, and of absorbing alimentary material into their own substance for its nutrition. The *Bathybius*, from the "globigerina mud," referred to on page 93, seems to have been an indefinite expansion of such protoplasm or bioplasm.

II. Rhizopods.—This term (meaning root-footed) is applied to such masses of sarcode or bioplasm as extend long processes, called *pseudopodia*, as prehensile or locomotive organs (Plate XII, Fig. 116). The Rhizopods are either indefinitely organized jelly, like *Monera*, or attain a covering or envelope of membrane called *ectosarc*, while the thin contents are termed *endosarc*. The first order of Rhizopods, *Reticularia*, consist of indefinite extensions of freely branching and mutually coalescing bioplasm. The second order, *Radiolaria*, have rod-like radiating extensions of the ectosarc, which do not coalesce. The order *Lobosa* are lobose extensions of the body itself, as in the

Amœba princeps already described. Some of this latter order, as *Arcella* and *Difflugia*, are testaceous. In Arcella the test is a horny membrane, analogous to the chitine which hardens the integuments of insects. In Difflugia the test is made up of minute particles of gravel, shell, etc., cemented together. From the opening the amœboid body puts forth its pseudopodia (Plate XII, Fig. 117). Connected with Rhizopods are three remarkable series of forms, generally marine, and distinguished by skeletons of greater or less density, which afford many objects of interest to the microscopist. These are the *Foraminifera*, the *Polycystina*, and the *Sponges* or *Porifera*. The shells of the Foraminifera are calcareous, and those of Polycystina siliceous; both are perforated with numerous apertures, which in Polycystina are often large. We have previously referred to these forms as occurring in a fossil state.

Some Foraminifera have porcellanous, and others vitreous or hyaline shells, usually many-chambered, and of every shape between rectilinear and spinal. Most of them are microscopic, but some are of considerable size, as the *Orbitolites*, which are found in tertiary limestones in Malabar. The Nummulitic limestone, which extends over large areas of both hemispheres, and of which the pyramids of Egypt are built, is composed of the remains of the genus *Nummulina;* and the *Eozoon Canadense* has been shown by Drs. Dawson and Carpenter to belong to the Foraminiferal type.

In some Foraminifera the true shell is replaced by a sandy envelope, whose particles are often cemented by phosphate of iron. Dr. Carpenter, whose researches have largely extended our knowledge of this group, pertinently remarks that "there is nothing more wonderful in nature than the building up of these elaborate and symmetrical structures by mere jelly specks, presenting no trace whatever of that definite 'organization' which we are accus-

tomed to regard as necessary to the manifestations of conscious life."*

The *Polycystina*, like the Foraminifera, are beautiful objects for the binocular microscope, with the black-ground illumination by the Webster condenser, the spot-lens, or the paraboloid.

The *Porifera* or sponges begin life as solitary Amœba, and amid aggregations formed by their multiplication, the characteristic spicules of sponge-structure make their appearance. In one group, the skeleton is a siliceous framework of great beauty. In *Hyalonema*, the silica is in bundles of long threads like spun glass. Sometimes sponge spicules are needle-like, straight or curved, pointed at one or both ends; sometimes with a head like a pin, furnished with hooks, or variously stellate. Dr. Carpenter thinks it probable that each spicule was originally a segment of sarcode, which has undergone either calcification or silicification (Plate XII, Fig. 118).

III. Infusorial Animalcules.—From the earliest history of the microscope, the minute animals found in various infusions or in stagnant pools, etc., have attracted attention. We owe to Professor Ehrenberg the first scientific arrangement of this class, and although more extended observations have changed his classification, yet many of his views are still accepted by the most recent investigators. Ehrenberg divided this class into two groups, which represent very different grades of organization. The first he called *Polygastrica* (many-stomached) from a view of their structure, which subsequent examinations have not confirmed. The other group is that of *Rotifera* or *Rotatoria*, a form of animal life which is most appropriately classed among *worms*. The term *Infusoria* is now applied to those forms which Professor Ehrenberg

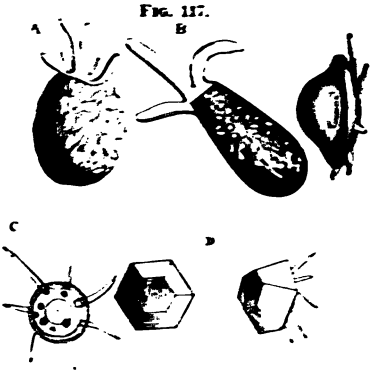
* The Microscope and its Revelations, by W. B. Carpenter, M.D., LL.D., etc.

PLATE XII.

Fig. 116.

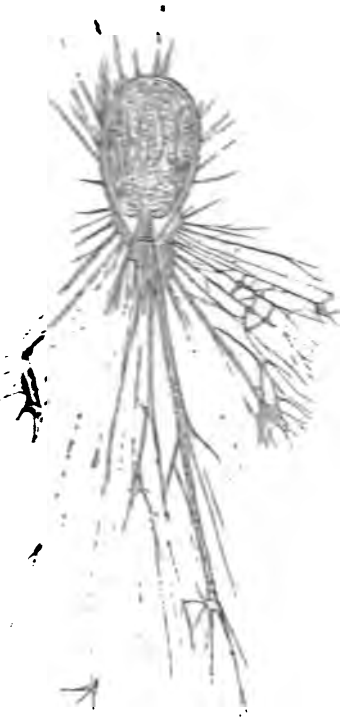
Monera Amœba.

Fig. 117.



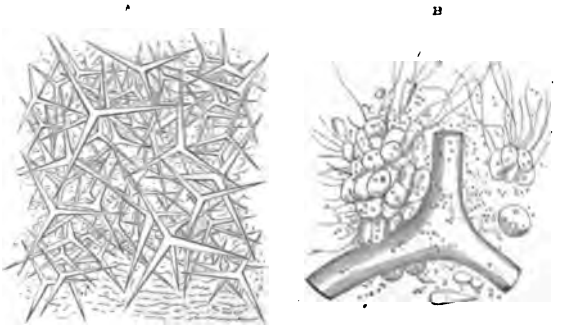
A, *Difflugia proteiformis*; B, *Difflugia oblonga*; C, *Arcella acuminata*; D, *Arcella dentata*.

Fig. 118.



Gromia oviformis, with its pseudopodia extended.

Fig. 119.



Structure of *Grantia compressa*: B, small portion highly magnified.

called polygastric animalcules. Yet a large section described by him in this connection, including the *Desmidiaceæ*, *Diatomaceæ*, *Volvocineæ*, and other protophytes, have been transferred by naturalists to the vegetable kingdom.

The bodies of the Infusoria consist of sarcode or bioplasm, having an outer layer of firmer consistence. Sometimes the integument is hardened on one side so as to form a shield, and in other cases it is so prolonged and doubled upon itself as to form a sheath or cell, within which the animalcule lies. The form of the body is more definite than that of *Amœba*, so as to be characteristic of species. It may be oblong, oval, or round; and some kinds, as *Vorticella*, are attached to a footstalk, which has the power of contracting in a spiral coil. No distinct muscular structure can be detected in the Infusoria, yet the general substance of the body is contractile. In most species short hair-like filaments or cilia project from the surface, sometimes arranged in one or more rows round the mouth, and moving to all appearance under the influence of volition. In others there are one or two flagelliform filaments, or long anterior cilia with vibratile ends. Others, again, have setæ or bristles, which assist in locomotion. The motions of some are slow, and of others quite rapid.

The interior of the sarcode body exhibit certain roundish spots, sometimes containing Diatoms or other foreign substances. They have been called gastric vesicles, cells, spaces, or sacculi. They are only visible from their contents, and seem to be mere spaces without a living membrane. If a little indigo or carmine is diffused in the water which contains the Infusoria, the cavities will soon be filled and become distinct. If watched carefully they will appear to move round the body of the animal, and as the pigment escapes at some part of the surface, the spots will disappear. Ehrenberg regarded these spots as so many stomachs arranged about a common duct, but the common opinion at present regards them as temporary

digestive sacs made by the inclosure of food by the soft bioplasm.

In addition to the "vacuoles" described, contractile vesicles are seen which contract and dilate rhythmically, and do not change their position. They have been considered to serve for respiration.

Most of the Infusoria multiply by self-division (Plate XIII, Fig. 119), and at certain times undergo an encysting process, much resembling the "still" condition of Protophytes, and like that serving for preservation under circumstances which are unfavorable to ordinary vital activity. The gemmules or progeny which result from the bursting of the cyst do not always resemble the parent in form. The recent researches of Drs. Dallinger and Drysdale have shown considerable variety in the life history of the Infusoria. In some instances the product of the encysting process was not a mass of granules, but an aggregation of minute germinal particles not more than $\frac{1}{20000}$th of an inch in diameter, and capable of resisting heat, either by boiling or by dry heating up to 300° F.

The observations of M. Balbiani show that in many of the Infusoria, male and female organs are combined in the same individual, but that a congress of two is necessary for the impregnation of the ova, those of each being fertilized by the spermatozoa of the other.

There is also a curious tribe of suctorial animalcules called *Acinetæ*, which put forth tubular prolongations which penetrate the bodies of other species and grow in their interior as parasites.

The systematic arrangement of the Infusoria is yet unsettled. Ehrenberg's families, excluding those now placed among Algæ or Rhizopods, are as follows:

A. Intestinal tube absent.
  Body variable, without cilia.
    Carapace absent, ... ASTASIÆA.
    Carapace present, ... DINOBRYINA.
  Cilia or setæ present.
    Carapace absent, ... CYCLIDINA.
    Carapace present, ... PERIDINÆA.
B. Intestinal tube present.
  Orifice single.
    Carapace absent, ... VORTICELLINA.
    Carapace present, ... OPHRYDINA.
  Two opposite orifices.
    Carapace absent, ... ENCHELIA.
    Carapace present, ... COLEPINA.
  Orifices differently placed.
    Carapace none.
      No tail, but a proboscis, . . TRACHELINA.
      Tail present, mouth anterior, . OPHRYOCERCINA.
    Carapace present, ... ASPIDISCINA.
  Orifices ventral.
    Carapace absent.
      Motion by cilia, ... COLPODEA.
      Motion by organs, ... OXYTRICHINA.
    Carapace present, ... EUPLOTA.

IV. ROTATORIA OR WHEEL ANIMALCULES.—These are microscopic, aquatic, transparent animals, of a higher organization than the Infusoria, and belonging in all probability to the class *Vermes*. Their chief interest to the microscopist is derived from the possession of a more or less lobed, retractile disk, covered with cilia, which, when in motion, resemble revolving wheels. They have also a complicated dental apparatus, and generally a distinct alimentary canal, and are reproduced by ova. Some are more or less covered by a carapace, and in most there is a retractile tail-like foot, sometimes terminated by a suctorial disk or a pair of claw-like processes. The nervous and vascular systems are not well known, although traces of them are seen. The young of some possess an eye which often disappears in the adult. They are re-

markably tenacious of life, having in some instances revived after having been kept dry for several years.

M. Dujardin divides the Rotifera into four groups or natural families:

1. Those attached by the foot, which is prolonged into a pedicle. It includes two families, the *Floscularians* and the *Melicertians*, in the first of which the sheath or carapace is transparent, and in the other composed of little rounded pellets (Plate XIII, Fig. 120).

2. The common *Rotifer* and its allies, which swim freely or attach themselves by the foot at will (Plate XIII, Fig. 121).

3. Those which are seldom or never attached, the *Brachionians* and the *Furcularians*. The former are short, broad, and flat, and inclosed in a sort of cuirass; the latter are named from a bifurcated, forcep-like foot (Plate XIV, Fig. 122).

4. The *Tardigrada* or water bears. These have no ciliated lobes, but are in other respects like their allies, and seem to be a connecting link between the Rotifers and worms. The segments of the body, except the head, bear two fleshy protuberances furnished with four curved hooks.*

V. Polyps.—The animals of this class were formerly called *Zoophytes*, or animal flowers. They are the most important of coral-making animals, although the Hydroids and Bryozoa, together with some Algæ, as the Nullipores, share with them the formation of coral, which is a secretion of calcareous matter. Dana's work on corals gives a classification, of which we present a summary.

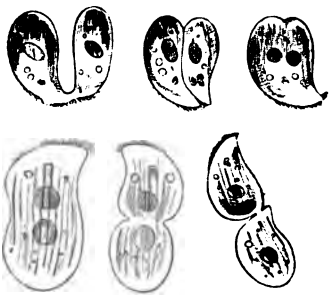
A good idea of a polyp may be had from comparison with the garden aster, the most common form of a polyp flower being a disk fringed with petal-like organs called tentacles.

The internal structure, like the external, is radiate, and

* Carpenter on the Microscope.

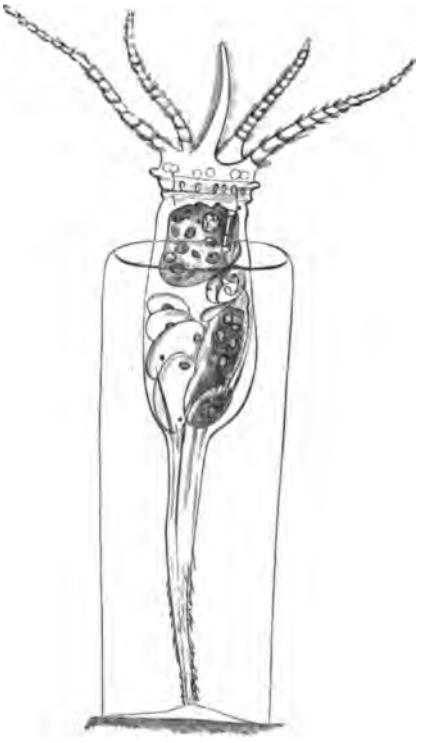
PLATE XIII.

FIG. 119.



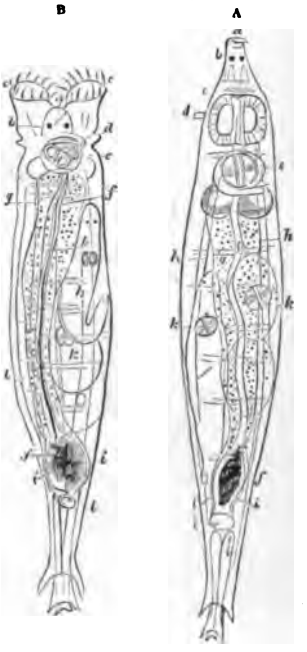
Fissiparous multiplication of *Chilodon cucullulus*.

FIG. 120.

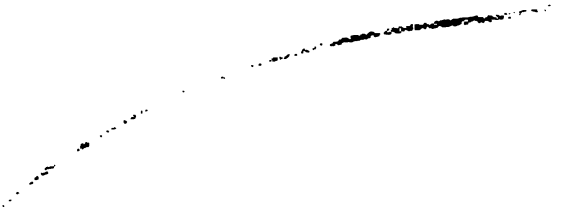


Stephanoceros Eichornii.

FIG. 121.



Rodifer vulgaris, as seen at A, with the wheels drawn in, and at B with the wheels expanded; *a*, mouth; *b*, eye-spots; *c*, wheels; *d*, calcar (antenna?); *e*, jaws and teeth; *f*, alimentary canal; *g*, glandular (?) mass enclosing it; *h*, longitudinal muscles; *i*, *i*, tubes of water vascular system; *k*, young animal; *l*, cloaca.



the cavity of the body is divided by septa into narrow compartments. The walls contain circular and longitudinal muscles, which serve for contraction of the body, which is afterwards expanded by an injection or absorption of water by the mouth.

The most interesting part of the structure of these animals, to the microscopist, is the multitude of lasso-cells, called also nettle-cells, *thread-capsules*, and *cnidæ*, which stud the tentacles and other parts of the body, and by means of which the prey of the polyp is at once pierced and poisoned. A small piece of the tentacle of a sea anemone placed in a compressorium under the microscope, and subjected to gentle pressure, will show the protrusion of many little dart-like processes attached to thread-like filaments. Many observations indicate the injection of a poison through these darts, which is instantly fatal to small animals. Plate XIV, Fig. 123.

The polyp has no circulating fluid but the results of digestion, mixed with salt water, no bloodvessels but the cavities among the tissues, and no passage for excrements except the mouth and the pores of the body. Reproduction is both by ova and by buds.

I. *Actinoid polyps* are related to the Actinea or sea anemone. The number of tentacles and interior septa is a multiple of six.

II. *Cyclophylloid polyps* have the number of tentacles and septa a multiple of four.

III. *Alcyonoid polyps* have eight fringed tentacles. The Alcyonium tribe are among the most beautiful of coral shrubs. The Gorgonia tribe has reticulated species like the sea fan, and bears minute calcareous spicules, often brilliantly colored. The Pennatula tribe is unattached, and often rod-like, with the polyps variously arranged.

VI. Hydroids.—The type of this class is the common Hydra, which is often found attached to leaves or stems of aquatic plants, etc. It is seldom over half an inch long.

... of a polyp, with long slender tentacles. ... these tentacles with their lasso-cells, it has no ... organs except a mouth and tubular stomach. Like ... Hydra, if its head be cut off another will grow ... each fragment will in a short time become a per... animal, supplying whatever is wanting, hence its name (Plate XIV, Fig. 124). The Hydra has the power of locomotion, bending over and attaching its head until the tail is brought forward, somewhat after the manner of a leech.

Compound Hydroids may be likened to a Hydra whose buds remain attached and develop other buds until an arborescent structure, called a *polypary*, is produced. The stem and branches consist of fleshy tubes with two layers, the inner one having nutritive functions, and the outer secreting a hard, calcareous, or horny layer. The individuals of the colony are of two kinds, the *polypite* or nutritive zooid, resembling the Hydra, and the *gonozooid*, or sexual zooid, developed at certain seasons in buds of particular shape.

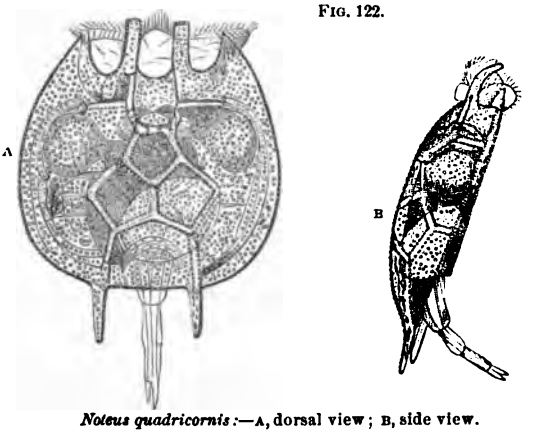
To mount compound Hydrozoa, or similar structures, place the specimen alive in a cell, and add alcohol drop by drop to the sea-water; this will cause the animals to protrude and render their tentacles rigid. Then replace the alcohol with Goadby's solution, dilute glycerin, or other preserving fluid.

VII. ACALEPHS, or *sea-nettles*, are of all sizes, from an almost invisible speck to a yard in diameter. They swarm in almost every sea, and are frequently cast upon the beach by the waves. They are transparent, floating free, discoid or spheroid, often shaped like a mushroom or umbrella, and their organs are arranged radiately round an axis occupied by the pedicle or stalk. They are furnished with muscular, digestive, vascular, and nervous systems. They were formerly divided into

1. *Pulmonigrada*, from their movements being effected

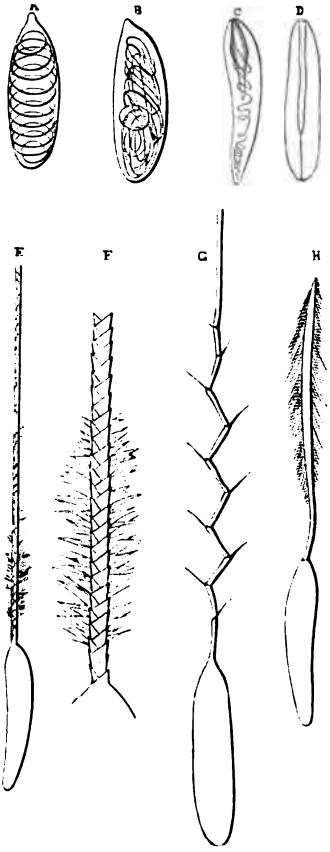
PLATE XIV.

FIG. 122.



Noteus quadricornis:—A, dorsal view; B, side view.

FIG. 123.



Filiferous capsules of Helianthoid Polypes:—A, B, *Corynactis Allmanni*; C, E, F, *Caryophyllia Smithii*; D, G, *Actinia crassicornis*; H, *Actinia candida*.

FIG. 124.

Hydra fusca in gemmation.

by a rhythmical contraction and dilation, as in *Rhizostoma*, etc. 2. *Ctenograda*, moving by narrow bands of vibratile cilia variously disposed over the body. In *Beroë* the cilia are transformed into flat fin-like shutters, arranged in eight longitudinal bands. In Venus's girdle, *Cestum Veneris*, the margins of a gelatinous ribbon are fringed with cilia. 3. *Physograda*, which move by means of an expansile bladder, as the *Physalia*, or Portuguese man of war. 4. *Cteniograda*, possessing a sort of cartilaginous skeleton, and furnished with appendages called cirri, serving as oars and for prehension, as *Porpita* and *Velella*. In the latter there is also a subcartilaginous plate rising at right angles from the surface supporting a delicate membrane, which acts as a sail.

This classification has been laid aside since the microscopic discovery of the close relationship between the Hydrozoa and the Medusoid Acalephs, and the latter are now subdivided into the "naked-eyed" and the "covered-eyed" Acalephs. The alternation of generations, page 126, is fully illustrated in this class. The embryo emerges as a ciliated gemmule, resembling one of the Infusoria. One end contracts and attaches itself so as to form a foot, while the other enlarges and becomes a mouth, from which four tubercles sprout and become tentacles. Thus a Hydra-like polyp is formed, which acquires additional tentacles. From such a polyp many colonies may rise by gemmation or budding, but after a time the polyp becomes elongated, and constricted below the mouth. The constricted part gives origin to other tentacles, while similar constrictions are repeated round the lower parts of the body, so as to divide it into a series of saucer-like disks, which are successively detached and become Medusæ Plate XV. Figs. 125, 126.

VIII. Echinoderms.—This class includes the star-fishes, the sea-urchins or sea-eggs, the sea-slugs, and the crinoids or stone lilies of former ages. If we imagine a polyp with

a long stem to secrete calcareous matter, not merely externally, but in the substance of its body and tentacles, such polyp when dried would present some such appearance as the fossil Encrinoid Echinoderms of past times. The imagination of such a polyp without a stem, and having sucker-like disks on its arms, will give us the picture of a star-fish (*Asterias*). Imagine the rays diminished and the central part extended, either flat or globular, and we have the form of *Echini* with the spines removed. The *Holothuriæ* have elongated membranous bodies, with imbedded spiculæ.

The structure of Echinoderms is quite complex, and belongs to comparative anatomy rather than microscopy, yet some directions for the study of these forms is essential to our plan.

Thin sections of the shells, spines, etc., may be made by first cutting with a fine saw, and rubbing down with a flat file. They should be smoothed by rubbing on a hone with water, cemented to a glass slip with balsam, and carefully ground down to the required thickness. They may be mounted in fluid balsam.

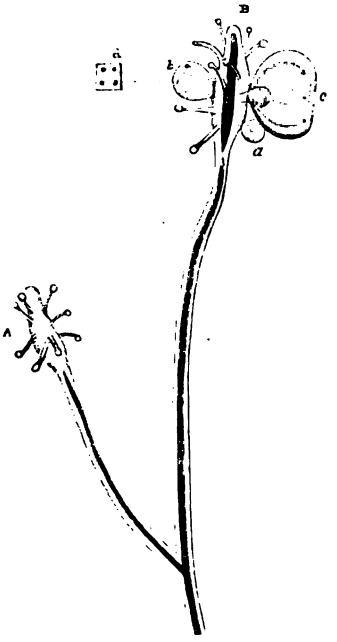
Many Echinoderms have a sort of internal skeleton formed of detached plates or spiculæ. The membranous integument of the Holothuriæ have imbedded calcareous plates with a reticulated structure, and they are often furnished with appendages, as prickles, spines, hooks, etc., which form beautiful microscopic objects.

The larva of an Echinoderm is a peculiar zooid, which develops by a sort of internal gemmation. One of the most remarkable of these larvæ has been called *Bipinnaria*.

IX. Bryozoa or Polyzoa.—Microscopic research has removed this class from the polyps, which they resemble, to the molluscan sub-kingdom. They have a group of ciliated tentacles round the mouth, but have a digestive system far more complex than polyps. They form delicate

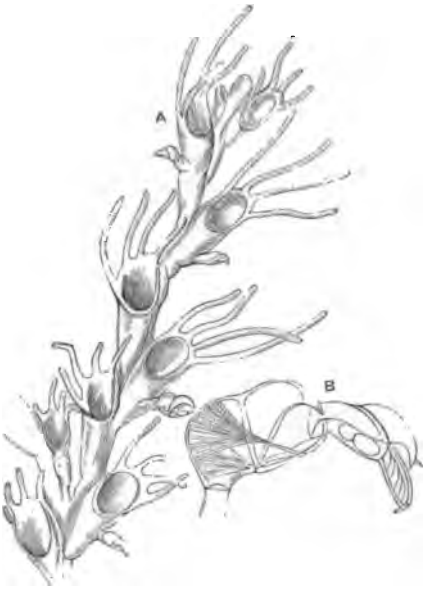
PLATE XV.

FIG. 125.



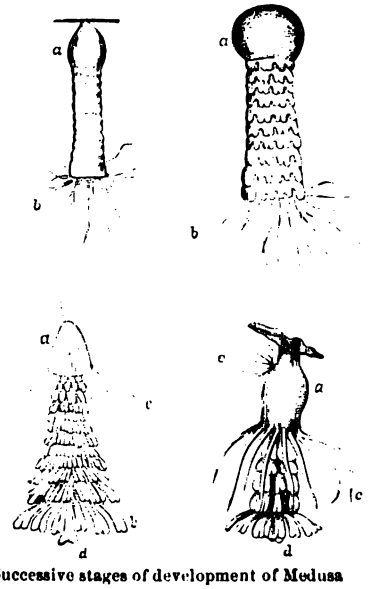
Development of Medusa buds in *Synchoryna Sarsii*.

FIG. 127.



A, Portion of *Cellularia ciliata*, enlarged; B, one of the "bird's-head" of *Bugula avicularia*, more highly magnified, and seen in the act of grasping another.

FIG 126.



Successive stages of development of Medusa buds from *Strobila larva*.

FIG. 128.

Sertularia cupressina:—A, natural size; B, portion magnified.

corals, either membranous or calcareous, made up of minute cabin-like cells, which are either thin crusts on sea-weeds, rocks, etc., or slender moss-like tufts, or groups of thin curving plates, or net-like fronds, and sometimes thread-like lines or open reticulations. The cells of a group have no connection with a common tube, as the Hydroids, but the alimentary system of each little Bryozoon is independent.

Many of the Polyzoa have curious appendages to their cells, of two kinds; the first are called birds'-head processes or *avicularia*. They consist of a body, a hinge or lower jaw-like process, and a stalk. The lower portion is moved by an elevator and depressor muscle, and during life the motion is constant. The second kind, or *vibracula*, is a hollow process from which vibratile filaments project (Plate XV, Figs. 127, 128).

X. TUNICATA.—These molluscs are so named from the leathery or cartilaginous tunic which envelops them, and which often contains calcareous spicula. Like the Bryozoa they tend to produce composite structures by gemmation, but they have no ciliated tentacles. They are of most interest to the microscopist from the peculiar actions of their respiratory and circulatory organs, which may be seen through the transparent walls of small specimens. The branchial or respiratory sac has a beautiful network of bloodvessels, and is studded with vibratile cilia for diffusing water over the membrane. The circulation is remarkable from the alternation of its direction.

The smaller Tunicata are usually found aggregate, investing rocks, stones and shells, or sea-weeds; a few are free.

Synopsis of the Families.

A. Attached; mantle and test united only at the orifices.

1. *Botryllidæ.*—Bodies united into systems.

2. *Clavelinidæ*.—Bodies distinct, but connected by a common root thread.

3. *Ascidiadæ*.—Bodies unconnected.

B. Free; mantle and test united throughout.

4. *Phlegradæ*.—Orifices near together.

5. *Salpadæ*.—Orifices at opposite ends.

XI. Conchifera. This class consists of bivalve molluscs, and is chiefly interesting to the microscopist from the ciliary motion on their gills and the structure of the shell.

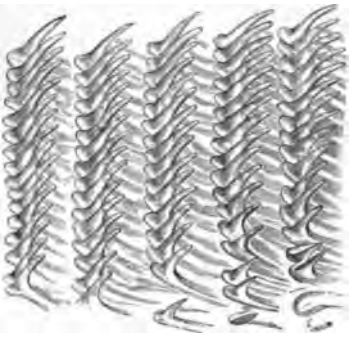
The ciliary motion may be observed in the oyster or mussel, by detaching a small piece of one of the bands which run parallel with the edge of the open shell, placing it on a glass slide in a drop of the liquid from the shell, separating the bars with needles, and covering it with thin glass; or the fragment may be placed in the live box and submitted to pressure. The peculiar movement of each cilium requires a high magnifying power. It appears to serve the double purpose of aeration of the blood and the production of a current for the supply of aliment.

Dr. Carpenter has shown that the shells of molluscs possess definite structure. In the *Margaritaceæ* the external layer is prismatic, and the internal nacreous. The nacreous or iridescent lustre depends on a series of grooved lines produced by laminæ more or less oblique to the plane of the surface. The shells of *Terebratulæ* are marked by perforations, which pass from one surface to another. The rudimentary shell of the cuttle-fish (of the class *Cephalopoda*), or "cuttle-fish bone," is a beautiful object either opaque or in the polariscope. Sections may be made in various directions with a sharp knife, and mounted as opaque objects or in balsam.

XII. Gasteropoda.—These molluscs are either naked, as the slug, or have univalve shells, as the snail, the limpet, or the whelk. As in the other classes referred to, the details of anatomical structure are full of interest;

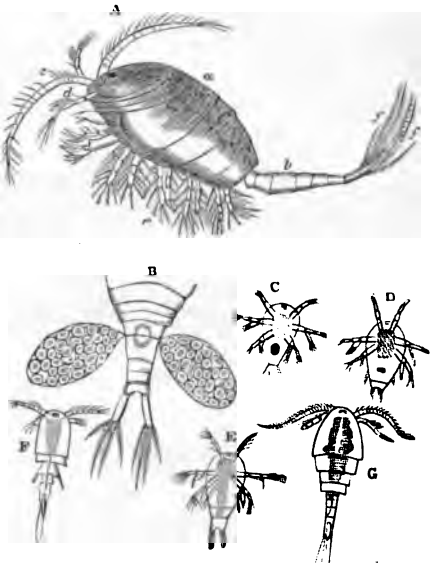
PLATE XVI.

FIG. 129.



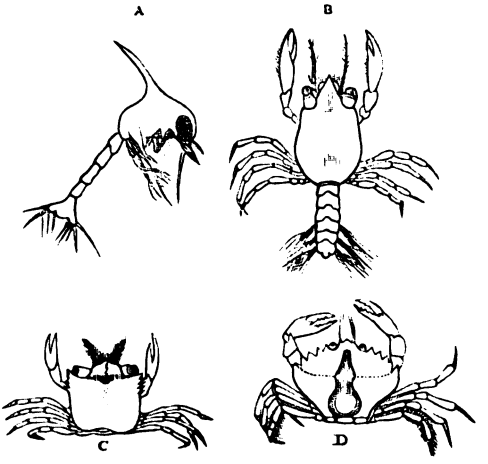
Palate of *Doris tuberculata*.

FIG. 130.



A, female of *Cyclops quadricornis*;—*a*, body; *b*, tail; *c*, antenna; *d*, antennule; *e*, feet; *f*, plumose setæ of tail;—B, tail, with external egg-sacs; C, D, E, F, G, successive stages of development of young.

FIG. 131.



Metamorphosis of *Carcinus mœnas*:—A, first stage; B, second stage; C, third stage, in which it begins to assume the adult form; D, perfect form.

but to the microscopist the palate, or tongue as it is called —a tube which passes beneath the mouth, opening obliquely in front, and which is covered with transverse rows of minute teeth set upon plates—presents characters of great value in classification. These palates require careful dissection, and when mounted in balsam become beautiful polariscope objects (Plate XVI, Fig. 129).

XIII. CEPHALOPODA.—The crystalline lens in the eye of the cuttle-fish is said to be of the same form as the well-known "Coddington lens." The skin of this class contains a curious provision for changing its hue, consisting of large pigment-cells containing coloring matter of various tints.

The suckers, or prehensile disks, on the arms of cephalopods often make interesting opaque objects when dried.

XIV. ENTOZOA.—These are parasitic animals belonging to the class of worms. They are characterized by the absence or low development of the nutritive system, and the extraordinary development of their reproductive organs. Thus the *Tænia* or tapeworm has neither mouth nor stomach, the so-called "head" being merely an organ for attachment, while each segment of the "body" contains repetitions of a complex generative apparatus.

Among the Nematoid or roundworms, the *Anguillulæ*, or little eel-like worms, found in sour paste, vinegar, etc., as well as the *Trichina spiralis*, inhabiting the voluntary muscles, are generally classified.

ORDER I. STERELMINTHA.—Alimentary canal absent or indistinct.

FAMILY 1. *Cestoidea.*—Tapeworms; body strap-shaped, divided into transverse joints; alimentary canal indistinct. The cystic Entozoa (*Echinococcus*, etc.) are nurse or larval forms of *Cestoidea.*

FAMILY 2. *Trematoda.*—Body mostly flattened; alimentary canal distinct; branched.

FAMILY 3. *Acanthocephala.*—Body flattened, transversely wrinkled; sexual organs in separate individuals.

FAMILY 4. *Gordiacea* (Hairworms).—Body filamentous, cylindrical; alimentary canal present; sexes distinct.

FAMILY 5. *Protozoidea or Gregarinida.*—Probably larval forms.

ORDER II. CÆLELMINTHA.—Alimentary canal distinct.

FAMILY 1. *Nematoidea* (Roundworms).—Body cylindrical, hollow; sexes separate.

The *Enoplidæ* tribe is distinguished by an armature of hooks or styles round the mouth. Most of them are microscopic.

XV. ANNULATA (Red-blooded Worms).—Some of these, as the *Serpula*, etc., are inclosed in tubes formed of a shelly secretion, or built up of grains of sand, etc., agglutinated together. Many have special respiratory appendages to their heads, in which the microscope will exhibit the circulation. The worms of the *Nais* tribe, also, are so transparent as to be peculiarly fitted for microscopic study of structure. The dental apparatus of the leech consists of a triangular aperture in a sucking disk, furnished with three semicircular horny plates, each bordered with a row of eighty to ninety teeth, which act like a saw.

ORDER 1. TURBELLARIA.—Body bilateral, soft, covered with vibratile cilia, not segmented; eyes distinct; sexless or hermaphrodite.

ORDER 2. SUCTORIA (Apoda).—Body elongate, ringed, without bristles or foot-like tubercles; locomotion by sucking-disks; no external branchiæ.

ORDER 3. SETIGRADA (Chœtopoda).—Body ringed, elongate, with feet or setigerous rudiments of them; external branchiæ usually present.

XVI. CRUSTACEA.—In the family of *Isopoda* the microscopist will find the *Ascellus vulgaris*, or water wood-louse, of great interest, as readily exhibiting the dorsal vessel and circulating fluids.

The family of *Entomostraca* contains a number of genera, nearly all of which are but just visible to the naked eye. They are distinguished by the inclosure of the body in a horny or shelly case, often resembling a bivalve shell, though sometimes of a single piece. The tribe of *Lophyropoda* (bristly-footed), or "water-fleas," is divided into two orders, the first of which, *Ostracoda*, is characterized by a bivalve shell, a small number of legs, and the absence of an external ovary. A familiar member of this order, the little *Cypris*, is common in pools and streams, and may be recognized by its two pairs of antennæ, the first of which is jointed and tufted, while the second is directed downwards like legs. It has two pairs of legs, the posterior of which do not appear outside the shell.

The order *Copepoda* has a jointed shell, like a buckler, almost inclosing the head and thorax. To this belongs the genus *Cyclops* (named from its single eye), the female of which carries on either side of the abdomen an egg capsule, or external ovarium, in which the ova undergo their earlier stages of development (Plate XVI, Fig. 130).

The *Daphnia pulex*, or arborescent water-flea, belongs to the order *Cladocera* and tribe *Branchiopoda*. The other order of this tribe, the *Phyllopoda*, has the body divided into segments, furnished with leaf-like members or "fin feet."

When first hatched, the larval Entomostraca differ greatly from the adult. The larval forms of higher Crustacea resemble adult Entomostraca.

The suctorial Crustacea, order *Siphonostoma*, are generally parasitic, mostly affixed to the gills of fishes by means of hooks, arms, or suckers, arising from or consisting of modified foot-jaws. The transformations in this order, as in the *Lernæa*, seem to be a process of degradation. The young comes from the egg as active as the young of *Cyclops*, which they resemble, and pass through a series of metamorphoses in which they cast off their locomotive

members and their eyes. The males and females do not resemble each other.

The order *Cirrhipeda* consists of the *barnacles* and their allies. In their early state they resemble the Entomostraca, are unattached, and have eyes. After a series of metamorphoses they become covered with a bivalve shell, which is thrown off; the animal then attaches itself by its head, which in the barnacle becomes an elongated pedicle, and in Balanus expands into a disk. The first thoracic segment produces the "multivalve" shell, while the other segments evolve the six pairs of cirrhi, which are slender, tendril-like appendages, fringed with ciliated filaments.

In the order *Amphipoda*, the *Gammarus pulex*, or fresh-water shrimp, and the *Talitrus saltator*, or sandhopper, may be interesting to the microscopist.

The order *Decapoda*, to which belong the crab, lobster, shrimp, etc., is of interest, from the structure of the shell and the phenomena of metamorphosis. The shell usually consists of a horny structureless layer exteriorly, an areolated stratum, and a laminated tubular substance. The difference between the adult and larval forms in this order is so great that the young crab was formerly considered a distinct genus, *Zoea* (Plate XVI, Fig. 131).

For the preservation of specimens of Crustacea, Dr. Carpenter recommends glycerin jelly as the best medium.

XVII. Insects.—Many insects may be mounted dry, as opaque objects. They may be arranged in position by the use of hot water or steam. Those which are transparent enough may be mounted in balsam, and very delicate ones in fluid. To display the external chitinous covering of an entire insect, it may be soaked in strong liquor potassæ, and the internal parts squeezed out in a saucer of water by gently rolling over it a camel's-hair brush. It may be put on a slide, and the cover fastened by tying with a thread. It should then be soaked in turpentine

until quite transparent, when it may be removed, the turpentine partially drained off, and a solution of balsam in chloroform allowed to insinuate itself by capillary attraction. Gentle heat from a spirit-lamp will be useful at this stage of the mounting.

Small insects hardly need soaking in caustic potash, as turpentine or oil of cloves will render them after awhile quite transparent, and their internal organs are beautifully seen in the binocular microscope. Thin sections of insects are instructive, and may be made with a section-cutter by first saturating the body with thick gum mucilage, and then incasing in melted paraffin.

Many insects and insect preparations are well preserved in glycerin.

The eggs of insects are often interesting objects, and should be mounted in fluid.

Wing cases of beetles are often very brilliant opaque objects. Some are covered with iridescent scales, and others have branching hairs. Many are improved by balsam, and this may be determined by touching with turpentine before mounting.

Scales of Lepidoptera, etc., may be exhibited in their natural arrangement by mounting a small piece of wing dry. If desired as test objects, a slide or thin cover, after having been breathed on, may be slightly pressed on the wing or body of the insect. The scales are really flattened cells, analogous to the epidermic cells of higher animals. Some have their walls strengthened by longitudinal ribs, while others, as the *Podurœ*, show a beaded appearance under high powers from corrugation. Dr. Carpenter believes the exclamation marks in the scales of the latter to be the most valuable test of the excellence of an objective.

Hairs of insects are often branched or tufted. The hair of the bee shows prismatic colors if the chromatic aberration of the object-glass is not exactly neutralized.

Antennæ vary greatly in form, and are often useful in

classification (Plate XVII, Fig. 132). Thus in the *Coleoptera* we have the *Serricornes*, or serrated antennæ; the *Clavicornes*, or clubbed; the *Palpicornes*, with antennæ no larger than palpi; the *Lamellicornes*, with leaf-like appendages to the antennæ; and the *Longicornes*, with antennæ as long or longer than the body. Nerve-fibres, ending in minute cavities in the antennæ, have been traced, which are supposed to be organs of hearing. The antennæ should be bleached to exhibit them. The bleaching process is also useful for other parts of insects. The bleaching fluid consists of a drachm of chlorate of potass in about two drachms of water, to which is added about a drachm of hydrochloric acid.

Compound eyes of insects are always interesting. They are quite conspicuous, and often contain thousands of facets, or minute eyes, called *ocelli* (Plate XVII, A B, Fig. 133). Besides these, insects possess rudimentary single eyes, like those of the *Arachnidæ*. These are at the top of the head, and are termed *stemmata* (Plate XVII, *a*, Fig. 133). To display the "corneules," or exterior layer of the compound eye, the pigment must be carefully brushed away after maceration. A number of notches may then be made around the edge, the membrane flattened on a slide, and mounted in balsam. Vertical sections may be made while fresh, so as to trace the relations of the optic nerve, etc. The dissecting microscope and needles will be found useful (Plate XVII, Fig. 132).

Mouths of insects present great varieties. In the beetles the mouth consists of a pair of mandibles, opening laterally; a second pair, called maxillæ; a labrum or upper lip; an under lip or labium; one or two pairs of jointed appendages to the maxillæ, termed maxillary palpi; and a pair of labial palpi. The labium is often composed of distinct parts, the first of which is called the mentum or chin, and the anterior part the ligula or tongue. This latter part is greatly developed in the fly, and presents

PLATE XVII.

FIG. 132.

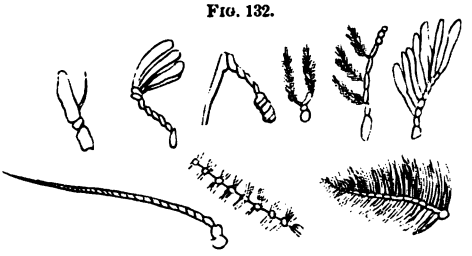


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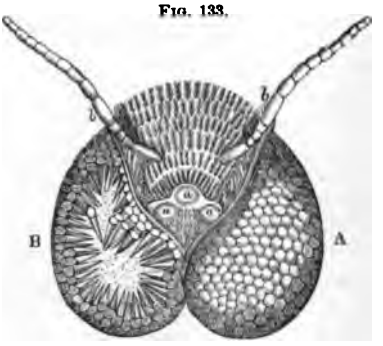
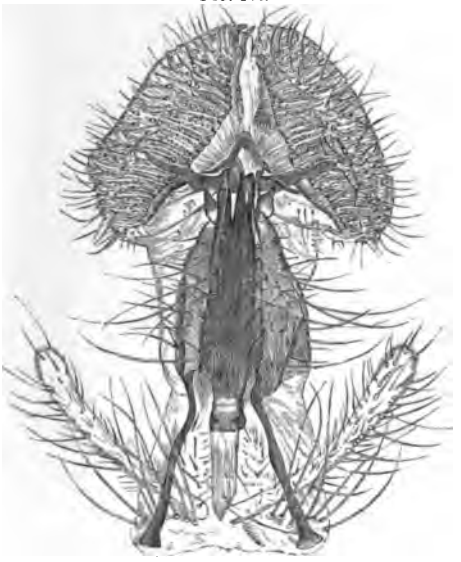
FIG. 133.



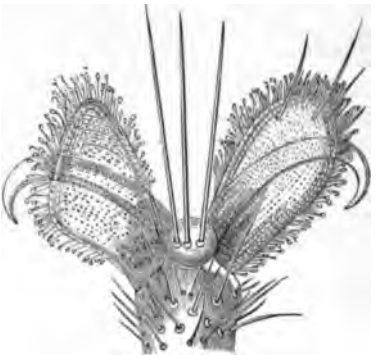
Compound Eyes of the *Bee*.

FIG. 134.



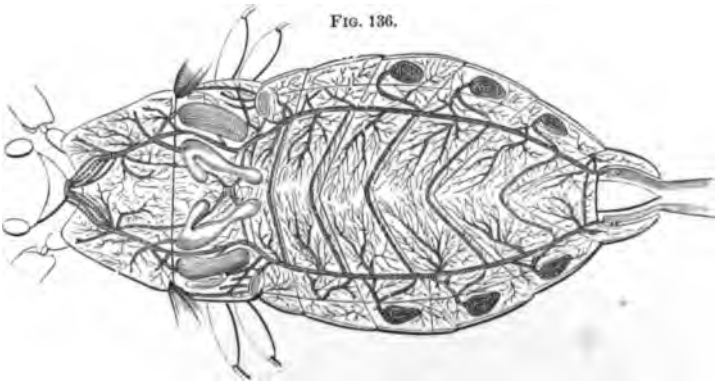
Tongue of common *Fly*.

FIG. 135.



Foot of *Fly*.

FIG. 136.



Tracheal system of *Nepa* (Water-scorpion).

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The alimentary canal in insects presents many diversities. As in higher animals, it is shorter in flesh-eaters than in feeders on vegetables. It consists of: 1. The œsophagus, which is sometimes dilated to form a crop. 2. The muscular stomach, or gizzard, whose lining membrane is covered with plates, or teeth, for trituration. 3. A cylindrical true stomach, in which digestion takes

place. The small intestine, terminating in the large intestine or colon. The colon of most insects in the imago or perfect state, never in larvæ or pupæ, contains from four to six organs of doubtful nature arranged in pairs. They are transparent, round, or oval tubercles projecting inside the colon, traversed by tufts of tracheæ, and sometimes with a horny ring at the base.

The salivary glands are sacs or tubes of variable form and length, terminating near the mouth. A distinct *liver* is absent, its function being performed by glandular cells in the walls of the stomach. Many insects, however, have special appendages to the stomach which secrete bile. Some have tubular cæca appended to the small intestine, probably representing a *pancreas*. In the interspaces of the various abdominal organs, is found a curious organ called the fatty body, which attains its development at the close of the larval period, and appears to form a reserve of nourishment for the pupa. It consists of fatty tubes held to a reticular tissue, and is traversed by the tracheæ.

The *Malpighian vessels* are slender, mostly tubular glands, usually uniting with each other, which open into the pyloric end of the stomach, and as uric acid has been found in them, are thought to serve the functions of a *kidney*. Some consider the renal organ to be represented by certain long vessels convoluted on the colon, and opening near the anus.

Other glandular organs occur in insects, as cysts in the integument, called glandulæ odoriferæ; poison glands, attached to the sting in many females; and silk-secreting glands coiled in the sides of the body and opening outside the mouth.

The heart is a long contractile vessel situated in the back. It is constricted at intervals. The posterior part acts as a heart, and the anterior represents an aorta, and conveys blood to the body. From the anterior end the

blood passes in currents in all directions, without vascular walls, running into the antennæ, wings, extremities, etc., and returning as a venous current, forming two lateral currents towards the end of the abdomen, it is brought by the diastole of the heart through lateral fissures existing in it.

The respiration is effected by means of *tracheæ*, two or more large vessels running longitudinally, giving off branches in all directions, and opening to the air by short tubes, connected at the sides of the body with orifices called *spiracles*. Aquatic larvæ often have branchiæ in the form of plates, leaves, or hairs, through which the tracheæ ramify (Plate XVII, Fig. 136).

The *nervous system* consists of a series of ganglia arranged in pairs, one for each segment of the body. They are situated between the alimentary canal and the under surface of the body, and are usually connected by longitudinal nervous cords. From the ganglia nerves are distributed to all parts.

The *muscular system* of insects is quite extensive. Lyonet dissected and described more than four thousand in the caterpillar of the goat-moth (*Cossus ligniperda*).

XVIII. ARACHNIDA.—This class of animals includes mites, ticks, spiders, and scorpions. They are destitute of antennæ; the head and thorax are united; they have simple eyes (ocelli), and eight jointed legs.

The cheese-mite, the "ticks," the itch-insect (*Sarcoptes scabies*), and the *Demodex folliculorum*, which is parasitic in the sebaceous follicles of the skin of the face, are common examples of *Acari*. They are best mounted in fluid.

The respiratory apparatus in spiders differs from that of insects, the spiracles opening into respiratory sacs, which contain leaf-like folds for aeration of blood. The spinning apparatus is also interesting.

The minute anatomy of vertebrated animals affords the

microscopist numerous specimens, but the details will be best understood from the following chapter.

As the classification of the Invertebrata is subject to great variation, the following table, after Nicholson, is added for the sake of comparison:

INVERTEBRATE ANIMALS.

SUB-KINGDOM I.—PROTOZOA.

CLASS I. GREGARINIDÆ.—Parasitic Protozoa, destitute of a mouth, and destitute of pseudopodia. Ex., Gregarina.

CLASS II. RHIZOPODA.—Simple or compound; destitute of a mouth; capable of putting forth pseudopodia.

CLASS III. INFUSORIA.—Generally with a mouth; no pseudopodia; with vibratile cilia or contractile filaments.

SUB-KINGDOM II.—CŒLENTERATA.

CLASS I. HYDROZOA.—Walls of the digestive sac not separated from those of the body cavity; reproductive organs external.

Sub-class 1. *Hydroida.*—Ex., Hydra. Tubularia (pipe-coralline). Sertularia (sea-fir).

Sub-class 2. *Siphonophora.*—Ex., Diphyes. Physalia (Portuguese man-of-war).

Sub-class 3. *Discophora.*—Ex., Naked-eyed Medusæ, or Jelly-fish.

Sub-class 4. *Lucernarida.*—Ex., Sea-nettles, or "Hidden-eyed" Medusæ.

CLASS II. ACTINOZOA.—Digestive sac distinct from the general cavity, but opening into it; reproductive organs internal.

Order 1. *Zoantharia.*—Ex., Sea-Anemones (Actinia). Reef-building corals.

Order 2. *Alcyonaria.*—Ex., Sea-pen. Red coral.

Order 3. *Ctenophora.*—Ex., Cestum (Venus's girdle).

SUB-KINGDOM III.—ANNULOIDA.

CLASS I. ECHINODERMATA.—Integument calcareous or leathery; adult radiate.

Order 1. *Crinoidea.*—Ex., Comatula.
Order 2. *Blastoidea.*—(Extinct.)
Order 3. *Cystoidea.*—(Extinct.)
Order 4. *Ophiuroidea.*—Ex., Brittle-star.
Order 5. *Asteroidea.*—Ex., Star-fish.
Order 6. *Echinoidea.*—Ex., Sea-urchins.
Order 7. *Holothuroidea.*—Ex., Sea-cucumbers.

CLASS II. SCOLECIDA.—Soft-bodied, cylindrical, or flat; nervous system not radiate; of one or two ganglia.

Order 1. *Tæniada.*—Ex., Tapeworms.
Order 2. *Trematoda.*—Ex., Flukes.
Order 3. *Turbellaria*—Ex., Planarians.
Order 4. *Acanthocephala.*—Ex., Echinorynchus.
Order 5. *Gordiacea.*—Ex., Hairworms.
Order 6. *Nematoda.*—Ex., Roundworms.
Order 7. *Rotifera.*—Ex., Wheel animalcules.

SUB-KINGDOM IV.—ANNULOSA.

DIVISION A. ANARTHROPODA.—Locomotive appendages not distinctly jointed or articulated to the body.

CLASS I. GEPHYREA.—Ex., Spoon-worms.

CLASS II. ANNELIDA. — Ex., Leeches (Hirundinidæ). Earth-worms (Oligochæta). Tube-worms (Tubicola). Sand-worms and Sea-worms (Errantia).

CLASS III. CHÆTOGNATHA.—Ex., Sagitta.

DIVISION B. ARTHROPODA. — Locomotive appendages jointed to the body.

CLASS I. CRUSTACEA.—Ex., Decapoda. Isopoda. Xiphosura. Cirripedia.

CLASS II. ARACHNIDA.—Ex., Podosomata (sea-spiders). Acarina (mites). Pedipalpi (scorpions). Araneida (spiders).

Class III. Myriapoda.—Ex., Centipedes.

Class IV. Insecta.— Ex., Anoplura (lice). Mallophaga (bird lice). Thysanura (spring-tails). Hemiptera. Orthoptera. Neuroptera. Diptera. Lepidoptera. Hymenoptera. Coleoptera.

SUB-KINGDOM V.—MOLLUSCA.

Division A. Molluscoida.—A single ganglion, or pair of ganglia; heart imperfect, or none.

Class I. Polyzoa.—Ex., Sea-mats (Flustra).

Class II. Tunicata.—Ex., Ascidia (Sea-squirts).

Class III. Brachiopoda.—Ex., Terebratula.

Division B. Mollusca Proper.—Three pairs of ganglia; heart of at least two chambers.

Class I. Lamellibranchiata.—Ex., Oyster. Mussel.

Class II. Gasteropoda. — Ex., Buccinium. Helix. Doris.

Class III. Pteropoda. Ex., Cleodora.

Class IV. Cephalopoda.

Order 1. Dibranchiata. Ex., Poulp. Paper Nautilus.

Order 2. Tetrabranchiata.—Ex., Pearly Nautilus.

CHAPTER XII.

THE MICROSCOPE IN ANIMAL HISTOLOGY.

In Chapter IX we described the elementary living substance, or bioplasm, from which all organized structures proceed, with an outline of its morphology, chemistry and physiology. In Chapter X we treated of Vegetable Histology, or the elementary tissues and organs which pertain to vegetable life. We now consider the

structure of formed material in animals, with special reference to the minute anatomy of the human body. Following the generalization of Dr. Beale, page 118, we may classify histological structures as follows:

A. INORGANIC AND ORGANIC ELEMENTS OR PABULUM.
Resulting in
B. BIOPLASM; or, O. H. C. and N., with other chemical elements, *plus*, The cause of life.
From this results:
C. FORMED MATERIAL, consisting of,
I. CHEMICAL PRODUCTS; Organic Compounds, etc.
II. MORPHOLOGICAL PRODUCTS. 1. Granules; 2. Globules; 3. Fibres; 4. Membrane.
Forming *Tissues*. 1. Simple; 2. Compound.
Arranged in *Organs*. 1. Vegetative; 2. Animal.

I. THE CHEMICAL PRODUCTS of Bioplasm are very numerous, and belong to the science of *Histo-Chemistry*. Our plan allows us to do little more than to enumerate the principal groups. It has already been stated that the true chemical structure of bioplasm, or living sarcode, (protoplasm in a living state) is unknown, since it is only possible to analyze the dead cell substance. Of the relation of the oxygen, hydrogen, carbon, and nitrogen, etc., which constitute its "physical basis," we can only speculate, or imagine. See *Chemistry of Cells and their Products*, page 122.

The chemical transformations of cell-substance into "formed material" consist chiefly, with water and mineral matter, of certain groups of *organic principles*, sometimes called albuminous or "protein" substances, and their nearer derivatives, as glutin-yielding and elastic matter, with fat and pigments. These materials are subject to constant secondary changes or transformations,

since they are not laid down in the living body once for all. They are also subject to constant decay, or ultimate decomposition. *Histo-Chemistry* must, therefore, be always a difficult study, since we can rarely isolate the tissues for examination, nor always tell when a substance is superfluous aliment, formative or retrogressive material. From a limited number of formative or histogenic materials, we have a host of changed or decomposition products.

Frey's *Histology and Histo-Chemistry*, Stricker's *Hand-Book of Histology*, and Beale's *Bioplasm*, are among the most useful books to the student in this department.

Frey subdivides the groups of organic principles as follows:

I. *Albuminous or Protein Compounds.*—Albumen. Fibrin. Myosin. Casein. Globulin. Peptones. Ferments?

II. *Hæmoglobulin.*

III. *Formative (Histogenic) Derivatives from Albuminous Substances.*—Keratin. Mucin. Colloid. Glutin-yielding substances. Collagin and Glutin. Chondrigen and Chondrin. Elastin.

IV. *Fatty Acids and Fats.*—Glycerin. Formic acid. Acetic acid. Butyric acid. Capronic acid. Palmitic acid. Stearic acid. Oleic acid. Cerebrin. Cholesterin.

V. *Carbohydrates.*—The Grape-sugar group, Cane-sugar group, and Cellulose group; or Glycogen. Dextrin. Grape-sugar. Muscle-sugar. Sugar of milk.

VI. *Non-Nitrogenous Acids.*—Lactic. Oxalic. Succinic. Carbolic. Taurylic.

VII. *Nitrogenous Acids.*—Inosinic. Uric. Hippuric. Glycocholic. Taurocholic.

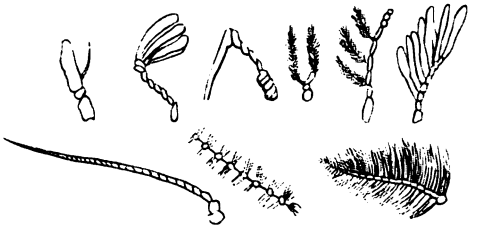
VIII. *Amides, Amido Acids, and Organic Bases.*—Urea. Guanin. Xanthin. Allantoin. Kreatin. Leucin. Tyrosin. Glycin. Cholin (Neurin). Taurin. Cystin.

IX. *Animal Coloring Matters.*—Hæmatin. Hæmin. Hæmatoidin. Urohæmatin. Melalin. Biliary pigments.

X. *Cyanogen Compounds.*—Sulpho-cyanogen.

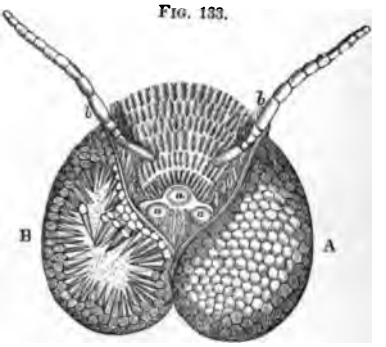
PLATE XVII.

FIG. 132.



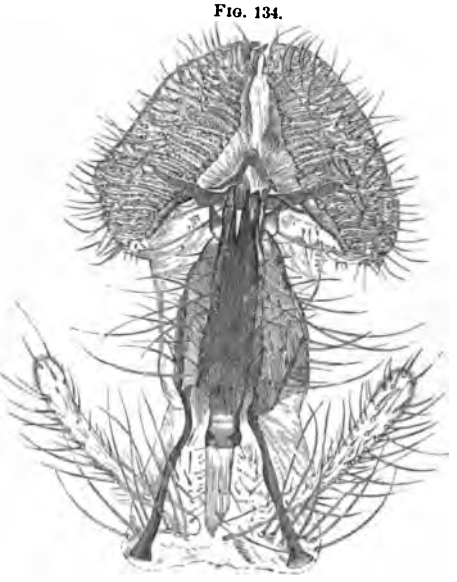
Various Antennæ of Insects.

FIG. 133.



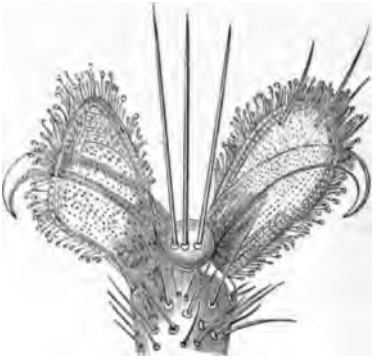
Compound Eyes of the *Bee*.

FIG. 134.



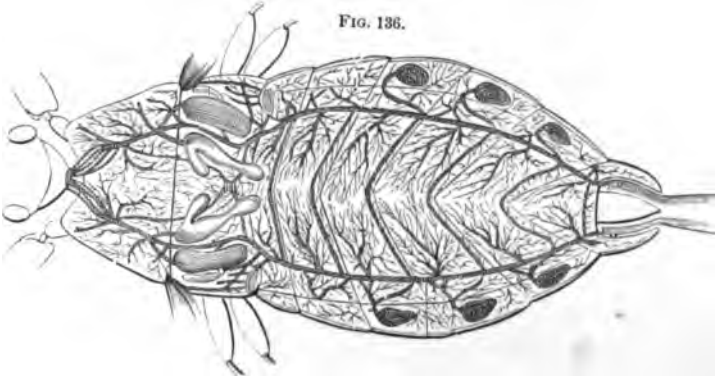
Tongue of common *Fly*.

FIG. 135.



Foot of *Fly*.

FIG. 136.



Tracheal system of *Nepa* (Water-scorpion).

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cause a precipitate in them. They are tinged by neutral solutions of carminate of ammonia. One-half to 1 per cent. of salt added to the staining fluid causes the nuclei only of Amphibian corpuscles to be stained. Chloroform, tannin, and other reagents, produce various changes, which suggest a wide field of research connected with Therapeutics.

The old opinion of the structure of red corpuscles represented them as vesicles consisting of a membrane and its contents, but Max Schultze, in 1861, showed that a membrane was not constant. This may be verified by breaking them under pressure.

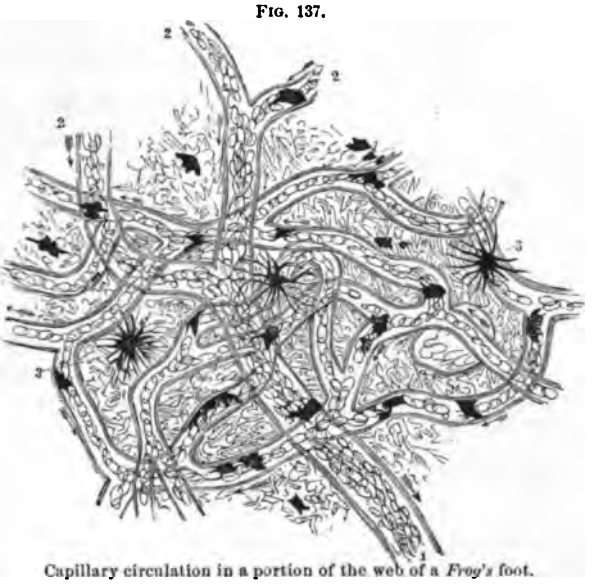
Brücke's experiment on the astringent action of boracic acid on the blood of *Triton*, repeated by Stricker and Lankester, shows the red corpuscles to possess a double structure. There is a body, called Ecoid; a porous, non-contractile, soft, transparent mass; and a retractile substance, or Zooid, containing the hæmoglobulin, which fills the interspaces of the Ecoid. The Zooid seems identical with simple cell-substance, or bioplasm.

3. *Colorless, or White Corpuscles*.—These appear to be simply masses of bioplasm of various sizes. Some are quite small, and many are larger than the red corpuscles. Their number is much smaller than the red disks, being about 1 to 350, or even less. In leucæmia and other diseases their relative number is much greater. In the blood of cold-blooded animals, and in that of vertebrata, if the normal temperature is continued by means of a warm stage, the amœboid motions are quite perceptible with a high magnifying power (Plate XVIII, Fig. 139). They may also be seen to take up small particles of matter into their interior, such as cinnabar, carmine, milk-globules, and even portions of the red globules.

Both red and white cells are forced through the uninjured walls of small vessels by impeded circulation, but the white cells thus migrate, by virtue of their vital con-

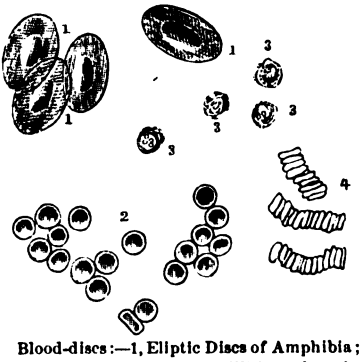
PLATE XVIII.

FIG. 137.



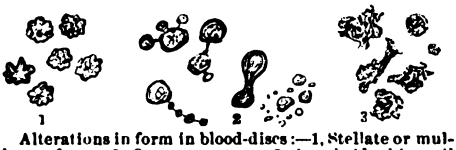
Capillary circulation in a portion of the web of a *Frog's* foot.

FIG. 138.



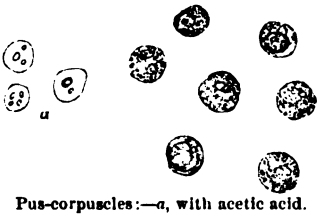
Blood-discs:—1, Elliptic Discs of Amphibia; 2, Human red-corpuscles; 3, White or lymph-corpuscle; 4, Rouleaux of red-discs.

FIG. 139



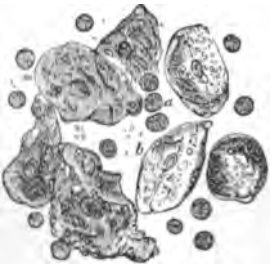
Alterations in form in blood-discs:—1, Stellate or mulberry form; 2, On warm stage; 3, Amœboid white-cell forms.

FIG. 140.



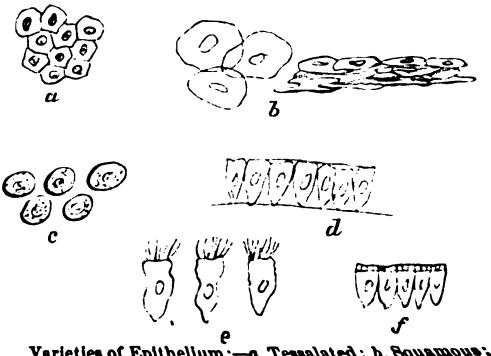
Pus-corpuscles:—*a*, with acetic acid.

FIG. 141.



Mucous corpuscles and epithelium.

FIG. 142.



Varieties of Epithelium:—a, Tessalated; b, Squamous; c, Glandular; d, Columnar; e, Ciliated.

tractility, in the healthy body, and in greater numbers in diseased states; in some cases re-entering the lymphatic circulation, and in others penetrating into various tissues. The pus-corpuscles appearing in the vicinity of inflamed parts are shown by this discovery, made by Waller and Cohnheim, to be nothing but migratory lymphoid or white cells of the blood. The change of form and place of these amœboid cells is readily seen by placing a drop of frog's blood on a glass cover, and inverting it over a moist cell. As it coagulates, a zone of serum extends round the clot, in which the migrated cells will be found.

The colorless cells originate in the chyle and lymph-systems, although some may come from the spleen and the medulla of bones, multiplying in the blood itself, and they pass into red corpuscles. Transitional forms have been found in the general mass of blood, in the spleen, and in the marrow of bones.

The white or colorless cells of blood are identical with the cells of chyle, lymph, pus, mucus, and saliva. They are often described under the term *leucocytes* (white cells.)

The leucocytes of saliva (salivary corpuscles) and of pus contain granules or globules of formed material, which exhibit for some time a peculiar dancing movement (see page 120).

When at rest, or in a lifeless condition, the white cells are of spheroidal form, and generally exhibit granules and globules of fat. Acetic acid develops a nucleus, and sometimes splits it into several (Plate XVIII, Fig. 140).

II. *Lymph and Chyle.*

The vessels of the lymphatic or absorbent system receive the liquid part of the blood which has passed from the capillaries, together with the products of decomposition in the tissues, and return them to the circulation. The lymphatics of the intestinal canal receive during

digestion a mixture of albuminous and fatty matters, which is known as *chyle*, and these vessels have obtained the name of *lacteals*. The cells in this fluid are leucocytes, identical with white cells in blood. They originate in the lymphatic glands and "Peyer's patches" of the intestine, and are the corpuscles of these organs which have been carried off by the fluid stream.

III. *Mucus.*

Is a tenacious semifluid substance which covers the surface of mucous membranes. It contains cast-off epithelial and gland-cells, and the *mucus corpuscle*, which, as we have before said, is identical with other leucocytes. *Synovial fluid* is of similar nature. It is now regarded as a transformation product of the epithelial cells, and not to originate as a secretion from special glands (Plate XVIII, Fig. 141).

2. Epithelium and its Appendages.

Epithelium (from επι, upon, and θαλλω, to sprout) is so called since it was formerly supposed to sprout from membrane. It is a tissue formed of cells more or less closely associated, which is found in layers upon external and internal surfaces. The cells are generally transparent, with vesicular, homogeneous, or granular nuclei, the latter being the remains of the original leucocyte or bioplast. In the older cells the nucleus is absent, the entire mass having been transformed.

The forms of epithelial cells vary according to situation or function. The original form is spheroidal, but changes by compression, etc.

1. Tessellated or pavement epithelium (Plate XVIII, *a*, Fig. 142). These are cells whose formed material is flattened, and which are united at their edges. They are sometimes hexagonal, and often polyhedral, in form.

Examples: Serous and synovial membranes; the pos-

terior layer of the cornea; the peritoneal surface; the interior of bloodvessels, and shut sacs generally.

2. Squamous or scaly epithelium. The cells are flat, and overlap each other at the edges (Plate XVIII, *b*, Fig. 142).

Examples: Epidermis; many parts of mucous membranes, as the mouth, fundus of bladder, vagina, etc.

3. Glandular epithelium (Plate XVIII, *c*, Fig. 142). The cells are round or oval bioplasts, often polyhedral from pressure, and the formed material is often soft.

Examples: Liver-cells, convoluted tubes of kidney, and interior of glands generally.

4. Columnar epithelium (Plate XVIII, *d*, Fig. 142). Cells cylindrical or oblong, arranged side by side. A bird's-eye view shows them similar to the tessellated form, hence they should be seen from the side.

Examples: Villi and follicles of intestine, ducts of glands, urethra, etc.

Some of the columnar or cylinder-cells have a thickened border or lid perforated with minute pores (Plate XVIII, *f*, Fig. 142). They are found in the small intestine, gall-bladder, and biliary ducts.

5. Ciliated epithelium (Plate XVIII, *e*, Fig. 142). These are cylindrical cells having vibratile cilia, whose motions produce a current in the surrounding fluid.

Examples: The upper and back nasal passages, the pharynx, bronchi, Fallopian tubes, etc.

The Hair.—Hairs are filiform appendages, composed of a modified epithelial tissue of rather complex structure. They originate in a follicle, which is a folding in of the skin. The shaft of the hair is the portion projecting above the skin, and the root is concealed in the hair-follicle. The bulb of the root is the rounded terminal part, which is hollow below, and rests on a papilla which rises from the floor of the follicle (Plate XIX, Fig. 143). Between the follicle and hair is a sheath, which is divided

into an external and internal portion. The cells of the hair may be isolated by sulphuric acid or solution of soda. They overlap each other like tiles, so as to present undulating or jagged lines across the surface of a fresh hair. The felting property of wool depends on the looseness of the overlapping. Air bubbles are often found in hair, especially in the medullary or axial portion, and give a dusky appearance to white hair. The granules of pigment are generally found in the cortical portion.

Nails are nothing more than modified cuticle, dependent for their growth on the vessels of the matrix or bed of the nail. Their epithelial cells may be demonstrated by soaking in caustic soda or potash.

Claws and hoofs have similar origin.

Teeth. The minute structure of dental tissue will be described hereafter, but as the enamel is generally considered to be of epithelial origin, some account of it belongs here.

The edge of the jaw is first marked by a slight groove, termed the dental groove, and is covered with a thick mass of epithelium, called the dental ridge (Plate XIX, Fig. III, 1, 2, *a*). The epithelium grows down in a process which has been called the enamel germ (1, *b*). This becomes doubled by the upward growth of the dental germ (2, 3, *f*), which originates from connective tissue. The epithelial cells become transformed into enamel columns or prisms.

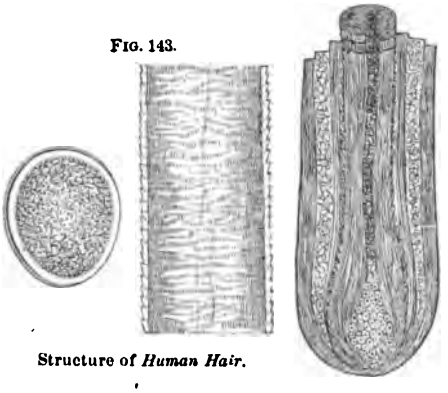
3. Connective Substances or Tissues.

The term connective tissue has been given to a variety of structures which probably start from the same rudiments, and have a near connection with each other. It is unfortunate that a name descriptive of function should be applied to structure, yet the present state of histology requires an account of substances thus called.

Connective tissues are all those which may be regarded

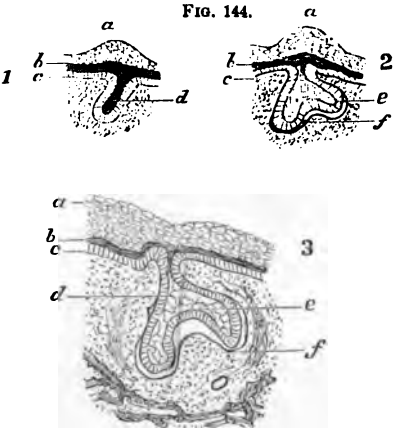
PLATE XIX.

FIG. 143.



Structure of *Human Hair.*

FIG. 144.

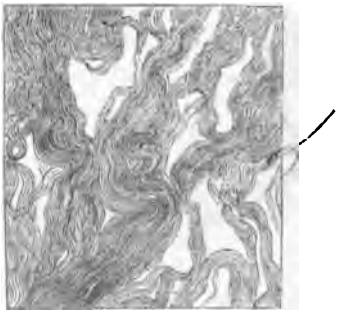


Development of the enamel:—*a*, dental ridge; *b*, young layer of epithelium; *c*, deep layer; *d*, enamel germ; *e*, enamel organ; *f*, dental germ.

FIG. 145.

Connective-tissue elements. From the Frog's Thigh:—*a*, contracted cell; *b*, ramified; *c*, *d*, motionless granular cells; *f*, fibrillæ; *g*, connective-tissue bundle; *h*, elastic fibre net-work.

FIG. 146.

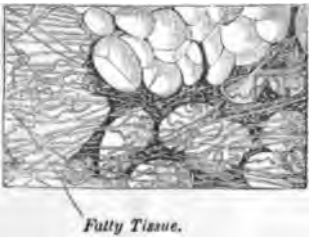


White Fibrous Tissue, from Ligament.

FIG. 147.

Yellow Fibrous Tissue, from Ligamentum Nuchæ of Calf.

FIG. 148.



Fatty Tissue.

as basement-membranes, supporting layers or investments for epithelial structures, blood, lymph, muscle, and nerves. It includes ordinary connective tissue (white and yellow fibrous tissues), cartilage, bone, corneal tissue, dentine, and fatty tissue.

Most of the difficulty found in the consideration of these tissues arises from discussions relative to the intercellular substance. Max Schultze and Beale agree in regarding it to originate from the protoplasm or bioplasm of cells.

The cells are, according to Frey, originally spheroidal, with vesicular nuclei, and between them is an albuminous intercellular substance—a product of the cells, or transformed cells—which usually undergoes fibrillation, while the cells become stunted, or develop into spindle-shaped or stellate elements. Calcification of the intercellular substance occurs in some of these tissues, as bone and dentine.

The cells of connective tissue present many varieties. Recklinghausen first observed migrating lymphoid cells or bioplasts in the cornea of the eye, the tail of the tadpole, the peritoneum, and in various other places. The exit of white corpuscles from the vascular walls renders it probable that these amœboid cells originate in the blood. Granular cells, of various forms—rounded, fusiform, and stellate—are also observed. Some of the stellate cells give off anastomosing branches. Pigment cells, filled with granular pigment, are also met with (Plate XIX, Fig. 145).

In its earliest stages, connective tissue consists of closely-compressed cells, but in the adult two principal forms have been distinguished; first, those networks and trabeculæ, developed from cells, which do not yield gelatin on boiling, and, secondly, fibrillar connective tissue composed of a gelatin-yielding substance. Of the first kind we notice the following varieties:

1. Independent masses of gelatinous or mucous tissue,

consisting of nucleated cells, giving off smooth anastomosing trabeculæ, as in the early stage of the vitreous humor of the eye and of the gelatinous tissue of the umbilical cord, etc.

2. Very delicate reticular tissue found in the eye and in the interior of nerve-centres.

3. A network filled with lymphoid cells (adenoid or cytogenous tissue) in the glands of the lymphatic system, and around the fasciculi of fibrillar connective tissue.

4. A coarser network in the ligamentum pectinatum of the human eye.

5. A tissue formed of fusiform and stellate cells, as in the interior of the kidneys

The second form referred to, or the *fibrillar connective tissue*, was the only form to which the term connective tissue was formerly applied. It is composed of gelatin-yielding fibrillæ, which may be split into skein-like portions of various breadth. (Plate XIX, Fig. 146.) Permanganate of potash stains it brown. Acetic and dilute mineral acids cause the tissue to swell so that the appearance of fibrillation is lost through compression, and the cells, or nuclei, are made manifest. Chloride of gold staining exhibits both fibrillæ and cells.

Elastic fibres (yellow elastic) (Plate XIX, Fig. 147) are apparent in all forms of connective tissue which have been made transparent by boiling, or acetic acid. They are non-gelatinizing, cylindric, slightly branched, or forming plexuses. In some fasciculi of fibrillar connective tissue, as seen after the action of acetic acid, elastic fibres appear in hoops, or spirals, around them. In the ligamentum nucleæ of the giraffe the elastic fibres are marked by transverse striæ, or cracks. Elastic fibres often form flattened trabeculæ, or are fused into elastic plates, or membranes, with foraminæ, as in arterial tunics.

The ligaments of the skeleton, the periosteum, perichondrium, aponeuroses, fasciæ, tendons, and generally all

the tunics of the body, afford examples of the fibrillar connective tissue.

Fatty Tissue.—The loose connective tissue contains in various parts great numbers of cells filled with fat. Their form is round, or oval, and are often divided into groups, or lobules, by trabeculæ. (Plate XIX, Fig. 148.) Each lobule has its own system of bloodvessels, which divide into such numerous capillaries that the smaller groups, and even individual fat-cells, are surrounded by vascular loops. Sometimes the contents of the cells appear in needle-shaped crystals, often collected in a brush-like form. Fat-cells seem to be chiefly receptacles for the deposit of superabundant oleaginous nutriment, and are analogous to the starch-cells in vegetables.

Cartilage.—This is formed of cells in an originally homogeneous intercellular substance. The only difference between what was formerly distinguished as cartilage and fibro-cartilage is that the matrix or intercellular substance of the latter is fibrous.

The cells, or cartilage-corpuscles, are nucleated, and lie in cavities of various sizes and form in the matrix (Plate XX, Fig. 149). Two nuclei often appear in one cell. It is yet a question whether the capsule and matrix are the secretion of the cells which has become solid, or a part of the body of the cell which has undergone metamorphosis.

The multiplication of cartilage-cells is endogenous. By segmentation, two, four, or a whole generation of daughter-cells, so called, may lie in the interior of a capsule. In this way growing cartilage may acquire a great number of elements.

In the ear of the mouse, etc., we observe a form of cartilage which is wholly cellular, and possesses no matrix (Plate XX, Fig. 150).

Bone, or osseous tissue, is formed secondarily from metamorphosed descendants of cartilage or connective-tissue cells, and is the most complex structure of this group. It

consists essentially of stellate ramifying spaces containing cells, and a hard, solid, intermediate substance. The latter is composed of glutinous material rendered hard by a mixture of inorganic salts, chiefly of calcium.

As all bones are moulded first in cartilage it was natural to conceive that they were developed by a transformation of cartilage. Much variety of opinion still exists respecting the process, but it is generally conceded that although cartilage may undergo calcification, true bone is not formed until the cartilage is dissolved. New generations of stellate cells appear in a matrix, which is first soft and then calcified. New bone may also grow from the periosteum by means of a stratum of cells called osteoblasts. The details of the process are too extensive for a treatise like the present. If sections of growing bone are decalcified with chromic acid and treated with carmine, the osteoblastic layers and adjacent youngest bony layer acquire an intensely red color, while the rest of the tissue, except the bone-corpuscles, remains uncolored.

Fine sections cut from a long bone longitudinally and transversely will show the microscopic structure, consisting of the *Haversian canals* (Plate XX, Fig. 151, *a*) surrounded with *concentric lamellæ* of compact structure (*b*, *b*). There are also intermediate and periosteal lamellæ (*c*, *d*). The cavities containing the bone-cells, or bioplasts (*e*, *e*,) are of various sizes, from 0.0181 to 0.0514 millimetres long, and from these *lacunæ* run the *canaliculi* in an irregular radiating course (*f*, *f*). In a balsam-mounted specimen these hollows sometimes retain air, by which the structure is rendered more apparent.

Dentine is the structure of which the teeth are most largely composed. It consists of minute tubes filled with *bioplasm*, which radiate from the central cavity of the tooth, the interspaces between the tubes being solidified by earthy salts so that the tissue is harder than bone.

Histologically a tooth may be said to be made of three

PLATE XX.

FIG. 149.

Section of the Branchial *Cartilage* of Tadpole.

FIG. 150.

Cellular Cartilage of Mouse's Ear.

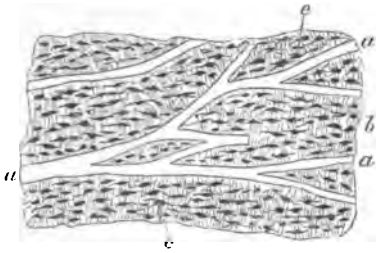
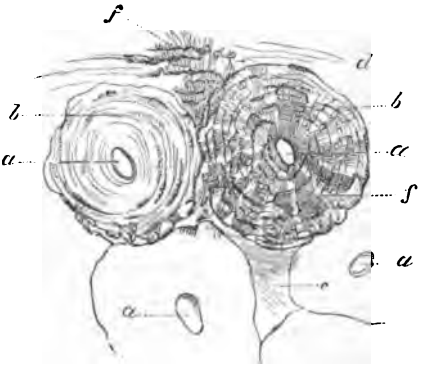
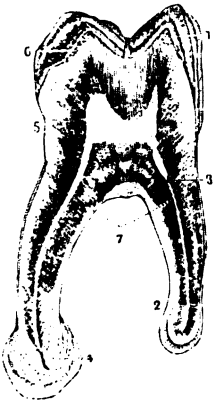


FIG. 151.



Longitudinal and transverse section of *Bone*:—*a*, Haversian canals; *b*, concentric lamellæ; *c*, intermediate; *d*, periostial lamellæ; *e*, bone-cells; *f*, canaliculi.

FIG. 152.

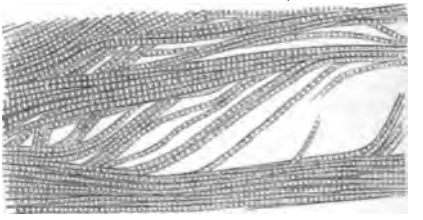


Vertical section of *Human Molar Tooth*:—1, enamel; 2, cementum or crusta petrosa; 3, dentine, or ivory; 4, osseous excrescence, arising from hypertrophy of cementum; 5, pulp-cavity; 6, osseous lacunæ at outer part of dentine.

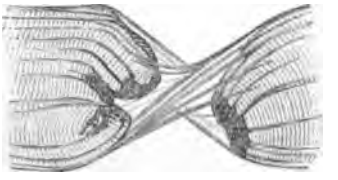
FIG. 153.

Involuntary Muscular-fibre.

FIG. 154.



Striated Muscular-fibre, separated into fibrillæ



Sarcolemma.

kinds of tissue: the *cement*, a bony substance, coating the root of the tooth, containing bone-cells and canaliculi, but no Haversian canals, the pulp in the central cavity of the tooth serving for the nutrition of the organ, as a large Haversian canal; the *dentine*, or ivory, constructed as above described; and the *enamel*, covering the crown, and consisting of columns or prisms, often hexagonal, which are the hardest and densest structures of the body (Plate XX, Fig. 152).

The development of enamel from epithelium has been referred to on page 192. The dental germ corresponds to a papilla of the mucous membrane, and in an early stage is covered by delicate stratified cells—the dentine cells, or odontoblasts—which produce dentine. Teeth are thus produced abnormally in other situations besides the jaws, as in ovarian cysts, etc.

Before the development of the first, or milk teeth, the rudiments of the permanent teeth exist as a fold or leaf of epithelium springing from the enamel germ.

II. COMPOUND TISSUES.

1. *Muscle.*—This is the tissue by which the principal movements of the body are performed. It consists of fibrin, which is endowed with special contractile power. It is of two kinds, the voluntary, pertaining to organs of voluntary motion, and the involuntary, found in situations which are not under the control of volition, as the coats of bloodvessels, alimentary canal, uterus, and bladder. The fibres of voluntary muscles are marked with transverse striæ. Involuntary muscular fibres are smooth, except in a few instances, as the fibres of the heart and some of those in the œsophagus, which are striated.

The fibres are connected with and invested by connective tissue, and arranged in parallel sets, with vessels and nerves in the intervals, and are attached to the parts they

are designed to move by tendon, aponeuroses, or some form of fibrous tissue. The organs or muscles thus formed are generally solid and elongated, but sometimes expanded.

Involuntary or *unstriped muscular fibres* are flat bands or spindle-shaped fibres with nuclei, which may be regarded as the remains of the formative bioplasm (Plate XX, Fig. 153). They are usually transverse, or interlace with each other on the walls of cavities and vessels. In the heart the fibres, though involuntary, are striped and branching. *Striped fibre* varies from $\frac{1}{80}$th to $\frac{1}{1500}$th inch in diameter. It is largest in insects, in which individual fibrils may be readily obtained, especially from the thoracic muscles. They are generally found in bundles of fibrils, splitting longitudinally or in disks, and each bundle is inclosed in a sheath or sarcolemma (Plate XX, Fig. 154).

The transverse striation of muscle is subject to much variation, and the precise nature of the sarcous elements which produce the appearance is yet a matter of dispute, but in all probability the ultimate elements are sarcous prisms or particles imbedded in a homogeneous mass, and by their mutual attraction, excited by various stimuli, the contraction of the fibre takes place.

For the purpose of observation, the connective tissue may be removed from muscular fibre by gelatinizing it with dilute sulphuric acid, and dissolving it at a temperature of 104° F. The nuclei of muscular fibre are seen after treating with acetic acid, and may be stained with carmine fluid, etc.

2. *Nerve-tissue.*—The term nerve was applied by the ancients to tense cords, as bow-strings, musical strings, etc., and was appropriated to the fibres now called nerves, because they deemed them to operate by tremors, vibrations, or oscillations, another instance of wrong naming of structure from an opinion respecting function. Hippocrates, Galen, and others, however, thought nerves were

hollow tubes, conveying fine ethereal fluids, termed animal spirits.

Nervous matter is soft, unctuous, and easily disturbed, hence it is necessary to examine it while fresh. Histologically it is divided into fibres and cells, imbedded in connective tissue.

Nerve-fibres are of two kinds, the medullated, or dark-bordered threads, and the pale, or non-medullated. Medullated fibres consist of a delicate envelope of connective tissue, called the neurilemma or primitive sheath, an axis-cylinder or albuminous portion, extending down the centre, and a portion composed of a mixture of albumen, cerebral matter, and fat, surrounding the axis-cylinder (Plate XXI, Fig. 155, A, B, C). This latter is the medullary sheath, or white substance of Schwann. It changes rapidly, so as to coagulate and become granular. Alkalies render it fluid, so as to exude in fat-like drops. Absolute alcohol, chromate of potass and collodion, contract the sheath, so as to permit the axis-cylinder, which is the essential part of the nerve, to protrude (Plate XXI, E, Fig. 155). Anilin, carmine, nitrate of silver, and chloride of gold stain the axis, while osmic acid blackens only the medullary sheath.

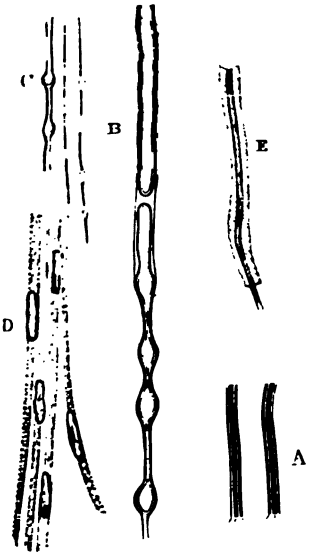
Non-medullary or pale nerve-fibres are regarded as embryonic or developmental forms (Plate XXI, D, Fig. 155). The ganglionic fibres of the sympathetic (Remak's fibres) are flat, homogeneous bands, with round or oval nuclei. Some have considered them as formed of connective tissue, but their nervous character is generally conceded.

Schultze and others regard the axis-cylinder as made up of extremely delicate fibrillæ.

Nerve-cells, or ganglion corpuscles, are of two kinds, those without and those with processes. The first are called apolar, and the latter unipolar, bipolar, or multipolar, according to the number of ramifications. The cells are nucleated, and inside the nucleus is usually

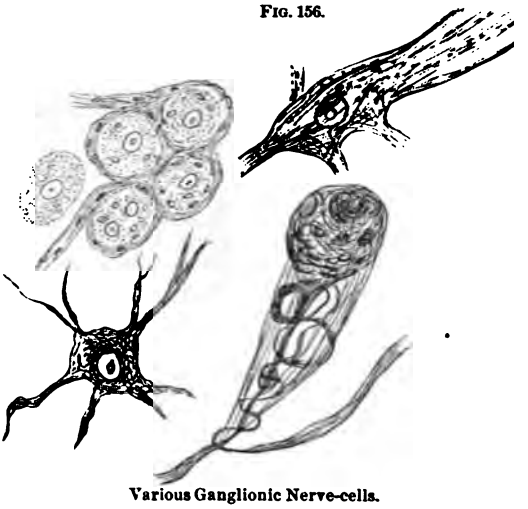
PLATE XXI.

FIG. 155.



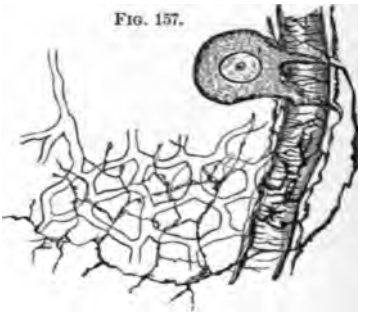
Nerve-fibres.

FIG. 156.



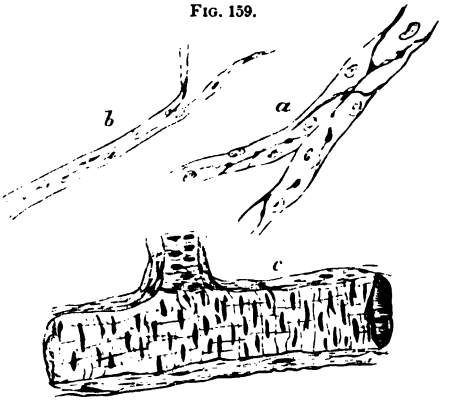
Various Ganglionic Nerve-cells.

FIG. 157.



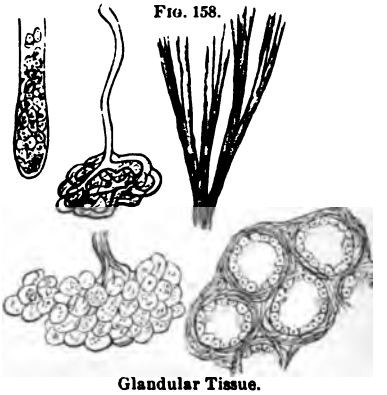
Self-regulating System of Ganglia—nerves, arteries, and capillaries.

FIG. 159.



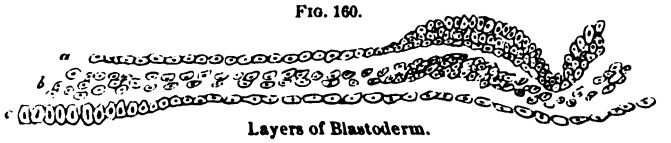
Vascular Tissue.

FIG. 158.



Glandular Tissue.

FIG. 160.



Layers of Blastoderm.

brane, through which the plasma transudes, and cells of glandular epithelium. A vascular network exists on the surface of the membrane, from which the material of the secretion is obtained. This membrane may be a simple follicle, or tube, as in the mucous membrane, or system of tubes, as in the kidneys, a convoluted tube, a simple open vesicle, a racemose aggregation of vesicles, or a close capsule which discharges itself by bursting. (Plate XXI, Fig. 158).

4. *Vascular Tissue.*—The smallest bloodvessels and lymphatics, called capillaries, are minute tubes, consisting of a series of flattened epithelial cells, and containing stomata, or openings through which white or red blood-corpuscles may occasionally pass (Plate XX, Fig. 159, *a*, *b*). The larger trunks have, in addition to the cellular layer, one of longitudinally striated connective tissue, a middle coat containing transverse muscular fibres, and an external coat of connective tissue (Plate XXI, Fig. 159). The distribution of the capillary bloodvessels is various, according to the nature or function of the organ or tissue in which they are found.

Development of the Tissues.

It has been stated, page 125, that reproduction in the higher animals consists of an ovum fecundated by contact with a sperm-cell, or spermatozoid. The ovum consists of a *germinal vesicle*, containing one or more *germinal* spots, and included within a *vitellus* (a yelk) which is surrounded by a *vitelline membrane*, which may have additional investments in the form of layers of albumen and of an outer coriaceous or calcified shell.

The first step in the development of the embryo is the division of the vitelline substance into *cleavage-masses*, at first two, then four, then eight, etc. This process of yelk-division may affect the whole yelk or a part of it, and results in the formation of a *blastoderm*, or embryogenic

tissue. This rudimentary embryonic tissue consists of three layers of cells, or germinal plates. The upper is the *corneous* layer, or epiblast, the middle one the *intermediate* plate, or mesoblast, and the lower the *intestinal glandular* layer, or hypoblast (Plate XXI, Fig. 160). From these the various tissues and organs are developed.

The outer plate produces the epithelium of the skin and its appendages, with the cellular elements of the glands of the skin, mammæ, and lachrymal organs. By a peculiar folding over the axis this plate also produces the elements of the brain and spinal cord, and the internal parts of the organs of special sense. The physiological significance of this layer is, therefore, very great.

The lower stratum of the blastoderm supplies the epithelium of the digestive tract, and the cellular constituents of its various glands, together with the liver, lungs, and pancreas.

The middle layer supplies the material for many structures. The whole group of connective substances, or tissues of support; muscular tissue; blood and lymph, with their containing vessels; lymph-glands, including the spleen, etc., all arise from this. The epithelial cells of such tubes and cavities as originate in this layer are regarded as different from those of true glands, and are more permeable to fluids. They have been termed false epithelium, or *endothelium*.

The following description, by Professor Huxley, will enable the student to form an idea of the general process of development. A linear depression, the *primitive groove*, makes its appearance on the surface of the blastoderm, and the substance of the mesoblast along each side of this groove grows up, carrying with it the superjacent epiblast. Thus are produced the two *dorsal laminæ*, the free edges of which arch over toward one another, and eventually unite, so as to convert the primitive groove into the cerebro-spinal canal. The portion of the epiblast which lines

this, cut off from the rest, becomes thickened, and takes on the structure of the brain, or *encephalon*, in the region of the head; and of the spinal cord, or *myelon*, in the region of the spine. The rest of the epiblast is converted into the epidermis.

The part of the blastoderm which lies external to the dorsal laminæ forms the *ventral laminæ;* and these bend downward and inward, at a short distance on either side of the dorsal tube, to become the walls of a ventral or visceral tube. The ventral laminæ carry the epiblast on their outer surfaces, and the hypoblast on their inner surfaces, and thus, in most cases, tend to constrict off the central from the peripheral portions of the blastoderm. The latter, extending over the yelk, incloses it in a kind of bag. This bag is the first formed and the most constant of the temporary, or fœtal appendages of the young vertebrate, the *umbilical vesicle.*

While these changes are occurring, the mesoblast splits, throughout the regions of the thorax and abdomen, from its ventral margin, nearly up to the *notochord* (which has been developed, in the meanwhile, by histological differentiation of the axial indifferent tissue, immediately under the floor of the primitive groove) into two *lamellæ*. One of these, the *visceral lamella*, remains closely adherent to the hypoblast, forming with it the *splanchnopleure*, and eventually becomes the proper wall of the enteric canal; while the other, the *parietal lamella*, follows the epiblast, forming with it the *somatopleure*, which is converted into the parietes of the thorax and abdomen. The point of the middle line of the abdomen at which the somatopleures eventually unite, is the *umbilicus.*

The walls of the cavity formed by the splitting of the ventral laminæ acquire an epithelial lining, and become the great *pleuroperitoneal* serous membranes (Huxley's *Anatomy of Vertebrated Animals*).

In addition to the umbilical vesicle, above described as

a temporary appendage, the fœtus has other special structures, derived from the blastoderm. Thus the somatopleure grows up over the embryo and forms a sac filled with clear fluid, the *amnion*. The outer layer of the sac coalesces with the vitelline membrane to form the *chorion*. The *allantois* begins as an outgrowth from the mesoblast. It becomes a vesicle, and receives the ducts of the *primordial kidneys* or *Wolffian bodies*, and is supplied with blood from the two hypogastric arteries which spring from the aorta. The allantois is afterwards cast off by the contraction of its pedicle, but a part of its root is usually retained, and becomes the permanent urinary bladder. In the Mammalia the allantois conveys the embryonic vessels to the internal surface of the chorion, whence they draw supplies from the vascular lining of the uterus.

Foster and Balfour recommend that the study of embryonic development should commence with the egg of a fowl taken at different times from a brooding hen, or an artificial incubator. The egg should be placed on a hollow mould of lead in a basin, and covered with a warm solution of salt (7.5 per cent.). It should be opened with a blow, or by filing the shell. With the naked eye or simple lens, lying across the long axis of the egg, may be seen the *pellucid area*, in which the embryo appears as a white streak. The mottled *vascular area*, with the blood-vessels, and the *opaque area* spreading over the yelk, may be observed. The blastoderm may be cut out with a sharp pair of fine scissors, floated into a watch-glass, freed from vitelline membrane and yelk, and removed (under the salt solution) to a glass slide. A thin ring of putty may then be placed round the blastoderm, which is covered with salt solution, and the thin glass cover put on. With a low-power objective many of the details of structure may be seen in an embryo of thirty-six to forty-eight hours incubation, as the heart, the neural tube, the first cere-

bral vesicles, the folds of the somatopleure and splanchnopleure, the protervertebræ, etc.

To prepare sections of the embryo, it must be first hardened by placing the slide containing it in a solution of 1 per cent. chromic acid for twenty-four hours. From this it should be removed to one of 3 per cent. for twenty-four hours more; then for a similar time in alcohol of 70 per cent., then in alcohol of 90 per cent., and lastly in absolute alcohol, where it may remain till required for section. Sometimes picric or osmic acid is used for hardening. The embryo may be stained by placing it in Beale's carmine fluid for twenty-four hours, and then replacing it in absolute alcohol for a day before it is cut. It may also be stained with hæmatoxylin if preferred. The specimen may be imbedded in paraffin, wax, and oil, or a mixture of four parts of spermaceti to one part of cocoa butter or castor oil. If there are cavities in the object, it is best to saturate it first with oil of bergamot. A little melted spermaceti mixture is poured on the bottom of a small paper box, and when solid the embryo is placed flat on it, the superfluous oil removed as far as possible, and the warm mixture poured on. Bubbles can be removed with a hot needle. A mark should be made of the exact position of the embryo. Sections may be cut with the section-cutter or a sharp razor, and if the spermaceti mixture is used, the razor should be moistened with olive oil. The sections should be floated from the razor to the slide, and treated with a mixture of four parts turpentine and one of creasote. They may then be mounted in balsam or dammar varnish.

The most instructive transverse sections of an early embryo will be through the optic vesicles, the hind brain, the middle of the heart, the point of divergence of the splanchnopleure folds, the dorsal region, and a point where the medullary canal is still open. For the unincubated blastoderm only one section, through the centre, is re-

quired to show the formative layers. In the later stages dissection is required, and is best performed with embryo preserved in spirit. If living embryos are placed in spirit, a natural injection of the vessels may be obtained.

III. ORGANS OF THE BODY.

Anatomists usually group the organs into systems, as the osseous, muscular, nervous, vascular systems, etc., but for histological study a classification based on physiological considerations may be more convenient for the student.

I. Vegetative Organs.

1. *Nutritive*, or organs pertaining to the absorption and distribution of pabulum, including the digestive and circulatory organs.

The mucous membrane of the intestinal canal contains many follicles and glands, whose secretions serve important offices in the preparation of the food. These will be referred to in the next section. The epithelium of the intestinal canal is columnar, except in the œsophagus, where it is laminated. Beneath the glandular layer of the stomach is a stratum of fibrous connective tissue and muscle fibres in two layers, an internal with transverse, and an external with longitudinal fibres. The tissue of the small intestine beneath the epithelium is reticular connective, entangling lymphoid cells. The structure of the large intestine is similar to that of the stomach. The villi of the small intestine begins at the pylorus, flat and low at first, but becoming conical, and finally finger-like in shape. The epithelium of the villi are columnar, with a thickened and perforated edge (Plate XXII, Fig. 161). Between the epithelial cells of the villi, peculiar "goblet-cells" are often found, which Frey supposes to be decaying cells. The reticular connective tissue of each villus is traversed by a vascular network, a lymphatic canal or lacteal, and delicate longitudinal muscular fibres. If the

villus is unusually broad, there may be more than one lacteal. The *lacteals* absorb the fluid known as chyle. They are blind ducts, and nitrate of silver injections show them to have the same structure as other lymphatics.

The *lymphatic radicles* are widely disseminated through all the tissues and organs of the body. They take up nutritive fluids, either from the alimentary canal, or such as have transuded from the capillaries into the interstices of the body, mingled with the products of decomposition, and convey them into the general circulation. Hyrtl's method of demonstrating these radicles is by passing a fine canula into the tissue containing lymphatics and forcing the injection by gentle pressure. They are either networks, analogous to capillaries, or blind passages which unite in reticulations. The structure of the vessels has already been described, page 201. Lymphatics and capillaries do not communicate directly. A lymph-canal may be surrounded by capillaries, or run alongside of a capillary, or a lymphatic sheath may envelop a bloodvessel. This latter plan is seen in the nervous centres, and has been called by His the *perivascular canal system.*

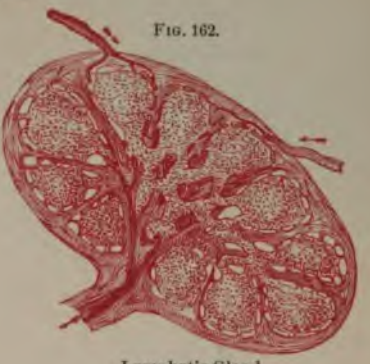
The larger lymphatic trunks are interrupted by nodular and very vascular organs, the *lymphatic glands.* These consist of the reticular connective tissue already described, surrounded by an envelope of ordinary fibrous tissue. One or more afferent lymphatic vessels penetrate the capsule, or envelope, and similar efferent vessels make their exit from the other side. Frey describes these glands as consisting of a cortical portion, follicles, and a medullary portion composed of the tubes and reticular prolongations of the follicles (Plate XXII, Fig. 162). There is a complicate system of communication between the follicles. The afferent vessel opens into the investing spaces of the follicle. These lead into the lymph-passages of the medullary portion, from the confluence of which the radicles of the efferent vessels are formed. The lingual follicular

PLATE XXII.

FIG. 161.

Intestinal Villus.

FIG. 162.



Lymphatic Gland.

FIG. 163.

Capillary net-work around *Fat-cells.*

FIG. 164.

Capillary net-work of *Muscle.*

FIG. 165.

Distribution of Capillaries in *Mucous Membrane.*

FIG. 166.

Distribution of Capillary bloodvessels, in *Skin of Finger.*

FIG. 167.

Villi of Small Intestine of Monkey.

FIG. 168.

Arrangement of the Capillaries of the air-cells of the *Human Lung.*

milk from the mammary gland; saliva, gastric juice and pancreatic fluid for digestion; mucus, sebaceous matter, tears, etc. Excretions result from waste or decomposition, and are incapable of further use; as carbonic acid, separated by the lungs; urea, uric acid, etc., by the kidneys; saline matters, from kidneys and skin; lactic acid, portions of bile, and some of the components of fæces.

The *sweat glands* in the skin are simply convoluted tubes lined with glandular epithelium and surrounded by a basket-like plexus of capillaries. The *sebaceous glands* are racemose, and often open into the hair-follicles.

The *salivary glands* are complex mucous glands, and the saliva secreted by them is a complex mixture. The terminal nerves of the submaxillary gland have been traced to the nuclei of the gland-cells.

The lingual glands, and parotid, partake of the nature of lymphoid organs. The glands of the œsophagus are racemose. In the stomach there are two kinds, the *peptic*, and gastric *mucous* glands. The peptic glands are blind tubes closely crowded together over the mucous membrane, lined with columnar epithelium near their openings, and gland-cells below. The mucous glands are numerous near the pylorus, and are usually branching tubes. The capillaries are arranged in long meshes about the peptic glands, and form a delicate network in the submucous tissue. Numerous lymphatic radicles communicate with lymph-vessels below the peptic glands.

The *small intestine* contains the racemose *glands of Brunner* and the tubular *follicles of Lieberkuhn*, together with the lymphoid follicles known as the solitary and agminated *glands of Peyer*. The glands of Brunner are confined to the duodenum, and their excretory duct and gland vesicle are lined by columnar epithelium. Lieberkuhn's follicles are found in great numbers all over the small intestine. Peyer's patches are most numerous in the ileum. They are accumulations of solitary glands,

and their structure is similar to the follicles of a lymphatic gland. The gland vesicles of the *pancreas* are roundish, and like other salivary glands it is invested with a vascular network with rounded meshes.

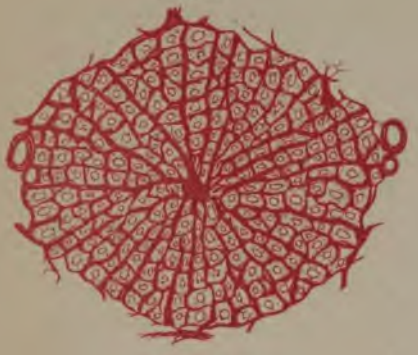
The liver is the largest gland connected with nutrition. Few animals are without a liver or its structural equivalent. In polyps the liver is represented by colored cells in the walls of the stomach cavity. In annelids the biliary cells cluster round cæcal prolongations of the digestive cavity. In crustacea the liver consists of follicles, and in insects of tubes, opening into the intestine. In all cases the essential elements are glandular cells containing coloring matter, oil, etc. In vertebrates some parts of the structure have not been decided upon without controversy.

In man the liver is a large, solid, reddish-brown gland, about twelve inches across, and six or seven inches from anterior to posterior edge, and weighing three or four pounds, situated in the right hypochondrium, and reaching over to the left. It is divisible into right and left lobes by the broad peritoneal ligament above, and the longitudinal fissure beneath. From the latter a groove passes transversely on the right side, lodging the biliary ducts, sinus of the portal vein, hepatic artery, lymphatics, and nerves, which are enveloped in areolar tissue, called the capsule of Glisson. From this groove ramifications of the portal canal extend through the liver, so numerous that no part of the hepatic substance is further than one-thirtieth of an inch from them. These ramifications carry the branches of the portal vein from which the capillary plexus surrounding the lobules begin, together with the bile-ducts, hepatic artery, etc.

The hepatic lobules are readily distinguished by the naked eye in many mammals, as the hog, but less easily in human liver. They consist essentially of innumerable gland-cells, and a complex network of vessels which tend towards the centre of the lobule, where their confluence

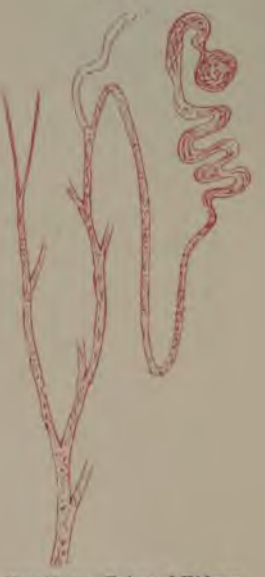
PLATE XXIII.

FIG. 169.



Lobule of Liver.

FIG. 170.



Uriniferous Tubes of Kidney.

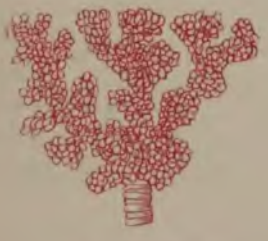
FIG. 171.

Blood-vessels of Kidney.

FIG. 173.

Tactile Papillæ.

FIG. 172.



Alveoli of Lung.

FIG. 174.

Taste-buds.

forms the radicle of the hepatic vein; while externally the lobules are bounded by branches of the portal vein and biliary canals (Plate XXIII, Fig. 169). The hepatic artery nourishes the proper connective tissue of the organ, and its venous radicles return the blood to the portal vein. The liver or bile-cells lie between the meshes of the capillaries, and are irregularly polyhedral from pressure, soft, granular, and nucleated. Brown pigment-granules and fatty globules are also found in the cells, and in disease in increased quantity. These bile-cells are inclosed in a delicate reticulated membrane, and Hering considers them to have a plexus of fine bile-ducts around them.

The kidneys are two large bean-shaped organs, each covered with a thin but strong fibrous envelope or tunic, which is continuous round the organ to the hilus, where the ureter leaves the gland and the bloodvessels enter. Even with the naked eye we may distinguish in a section of kidney the external granular cortex and the fibrous or striped medullary portion. The lines of the latter converge towards the hilus, and generally in a single conoid mass; but in man and some other animals this is divided into sections, called the pyramids, and between them the cortical substance is prolonged in the form of septæ, while both portions contain interstitial connective tissue. Both the cortical and medullary portions contain long branching glandular tubes, called the uriniferous tubes. In the medullary part these tubes are straight and divide at acute angles, while in the cortex they are greatly convoluted and terminate in blind dilatations, the capsules of Bowman. Staining with nitrate of silver shows the capsules to be lined with delicate pavement-epithelium. The convoluted tubes proceeding from the capsules, containing thick granular gland-cells, after numerous windings in the cortex, arrive at the medullary portion, where each pursues a straight course, and is lined with flat pavement-epithelium similar to the endothelium of vascular tissue.

Near the base of the pyramids these tubes curve upwards, forming the looped tubes of Henle. The recurrent tubes enlarge, and exhibit the ordinary cubical gland-cell. These tubes also become more tortuous, and empty into others of larger calibre, called collecting tubes. These are lined with low columnar epithelium, and uniting with similar tubes at acute angles, give exit to the urine at the apex of the papillæ in the pyramids (Plate XXIII, Fig. 170).

The bloodvessels of the kidney are as complex as the glandular tissue. Both vein and artery enter at the hilus of the kidney, and after giving twigs to the external tunic, proceed between the pyramids as far as their bases. Here they give off curving branches, forming imperfect arches among the arteries, and complete anastomosing rings on the veins. From the arterial arches spring the branches which bear the *glomeruli* of the cortical substance or Malpighian tufts (Plate XXIII, *a*, Fig. 171). The afferent vessel of the glomerulus subdivides, and after coiling and twisting within the capsule of Bowman, gives origin to the efferent vessel, by the union of the small branches thus formed. This efferent vessel breaks up into a network of fine capillaries, with elongated meshes surrounding the straight uriniferous canals. From the periphery of this network somewhat wider tubes are given off, which surround with rounded meshes the convoluted tubes of the cortex.

The long bundles of vessels between the uriniferous tubes of the medulla, communicating in loops or forming a delicate network round the mouths of the canals at the apex of the papillæ are called the *vasa recta*.

The *ureters*, like the pelvis of the kidney, consist of an external fibrous tunic, a middle layer of smooth muscular fibres, and an internal mucous membrane with a layer of epithelium. The *bladder* is covered externally with a serous membrane, the peritoneum. The female *urethra* is

lined by mucous membrane, with vascular walls full of folds, and containing, near the bladder, a number of mucous glands.

3. *Respiratory Organs.*—The lungs receive air by the trachea and venous blood from the right side of the heart to transmit to the left side. They may be compared, as to form and development, to racemose glands. The excretory ducts are represented by the bronchial ramifications, and the acini by the air-vesicles.

The ciliated mucous membrane of the bronchial twigs gradually loses its laminated structure until only a single layer remains. Their muscular layer also ceases before arriving at the air-cells. At the end of the last bronchial tubules we find thin-walled canals called *alveolar passages.* These are again subdivided and end in peculiar dilatations called primary pulmonary lobules, or *infundibula* (Plate XXIII, Fig. 172). The *air-cells*, *vesicles*, or *alveoli*, are saccular dilatations in the walls of the primary lobules, opening directly into a common cavity. Their walls consist of delicate membrane of connective tissue, often containing black pigment, probably from inhalation of carbonaceous matter, or a deposit of melanin.

The pulmonary artery subdivides, and follows the ramifications of the bronchi to the pulmonary vesicles. Here a multitude of capillary tubes form a network over the alveoli, only separated from the air by the most delicate membrane (Plate XXII, Fig. 168). In the frog we find the whole respiratory portion lined with a continuous layer of flattened epithelia. A similar lining is found in the mammalian fœtus, but in the adult the number and character of the epithelial scales is greatly changed. Large non-nucleated plates are seen with occasional traces of the original bioplasm. In inflammatory affections, however, these may multiply, giving rise to catarrhal desquamation.

4. *Generative Organs.*—The histology of the organs of reproduction is quite elaborate, and the plan of this work

only permits us to glance at the essential structures, which are the seminiferous tubules for the secretion of spermatozoa, in the male, and the ovary for the production of the germ, or ovum, in the female.

The *tubuli seminiferi* are a multitude of fine and tortuous tubules contained in the testis, with its accessory epididymis. They lie in the interstices of sustentacular connective tissue, and consist of membranous tubes filled with cells, which are said to possess amœboid motion. During the virile period these glandular tubes generate the spermatozoa, or microscopic seminal filaments. The shape of these spermatozoa is filiform in all animals, but vary in different species. In man they consist of an anterior oval portion, or head, and a posterior flexible filament, or tail. Different observers have taken different views as to the origin of these structures. Some suppose them the product of special cells, others trace them to the nuclei of the glandular epithelium, while others regard them as ciliated elements formed by the metamorphosis of entire cells. Their motions baffle all attempts at explanation, although quite similar to those of ciliated epithelium. The spermatozoa penetrate by their movements into the interior of the ovum, in order to impregnate it, and in the mammalia in considerable numbers.

The *ovary* may be divided into two portions: a medullary substance, which is a non-glandular and very vascular connective tissue, and a glandular parenchyma enveloping the latter. The surface of the ovary uncovered by peritoneum is coated with a layer of low columnar cells, called the germinal epithelium. Immediately under this is a stratum called the zone of the primordial follicles, or cortical zone. Here the young ova lie crowded in layers. They consist of granular bioplasm, containing fatty molecules and a spherical nucleus. They are probably developed by a folding in of the germinal epithelium. Toward the internal portion of the ovary the follicles become

more highly developed, and the ovum contained in them is also increased in size and enveloped in a distinct membrane. There are from twelve to twenty mature follicles in the ovarium, named, from their discoverer, Graafian follicles. Each has an epithelial lining, in which the ovum is imbedded. The capsule of the ovum is known as the *zona pellucida*, or *chorion*, and the albuminous cell-body is the *vitellus*. The nucleus is situated excentrically, and is called the *vesicula germinativa*, or germinal vesicle of Purkinje. Within it is a round and highly refractive nucleolus, the *macula germinativa*, or germinal spot of Wagner. A Graafian vesicle bursts and an ovum is liberated at every menstrual period. During the progress of the latter down the Fallopian tube to the uterus, impregnation may take place by the penetration of spermatozoa into its yelk. Then the inherent vital energies of the cell are aroused, and the process of segmentation begins. Unimpregnated ova are destroyed by solution. The ruptured and emptied Graafian vesicle becomes filled up with cicatricial connective tissue, which constitutes what is called the *corpus luteum*, after which it gradually disappears.

II. Organs of Animal Life.

1. *Locomotive.*—The microscopic structure of bone and muscle has been described in connection with elementary tissues. Tendons and fascias belong to the connective tissues.

2. *Sensory.*—The nervous apparatus of the body, whose histological elements were treated of on a previous page, has been classified physiologically into:

1. *The sympathetic system*, consisting of a chain of ganglia on each side of the vertebral column, with communicating cords or extensions of ganglia, visceral nerves, arterial nerves, and nerves of communication with the cerebral and spinal nerves. The chief structural differ-

ence between this and the cerebro-spinal system is that in the latter the nerve-cells form large masses, and the union of its parts is effected by means of central fibres, while in the sympathetic the cells are more widely separated, and union between them and with the cerebro-spinal axis is by means of peripheral fibres. The sympathetic is considered a motor and sensitive nerve to internal viscera, and to govern the actions of bloodvessels and glands.

2. *The cerebro-spinal system*, divided into:

(1.) A system of ganglia subservient to reflex actions, the most important of which is the spinal cord, where the gray or vesicular nervous matter forms a continuous tract internally.

(2.) A ganglionic centre for respiration, mastication, deglutition, etc., with a series of ganglia in connection with the organs of special sense: the medulla oblongata, with its neighboring structures; the mesocephalon, corpora striata, and optic thalami.

(3.) The cerebellum, a sort of offshoot from the upper extremity of the medulla, for adjusting and combining voluntary motions.

(4.) The cerebrum, cerebral hemispheres, or ganglia, which are regarded as the principal organs of voluntary movements. In the lower vertebrates the hemispheres are comparatively small, so as not to overlap the other divisions of the brain; but in the higher Mammalia they extend over the olfactory lobes and backward over the optic lobes and cerebellum, so as to cover these parts, while they also extend downward toward the base of the brain. In the lower vertebrates, also, the surface of the hemispheres is smooth, while in the higher it is complicated by ridges and furrows.

(5.) The cerebral and spinal nerves. The spinal nerves arise in pairs, generally corresponding with the vertebræ. Each has two roots, one from the dorsal, and one from the ventral region of its half of the cord. The former

root has a ganglionic enlargement, and contains only sensory fibres; the latter has no ganglion, and contains only motor fibres.

The cerebral nerves are those given off from the base of the brain. Some of these minister to special sensation, as the olfactory, optic, auditory, part of the glosso-pharyngeal, and the lingual branch of the trifacial nerves. Some are nerves of motion, as the motor oculi, patheticus, part of the third branch of the fifth pair, the abducens, the facial and the hypoglossal nerves. Others are nerves of common sensation, as the fifth, and part of the glosso-pharyngeal nerves. Others, again, are mixed, as the pneumogastric and spinal accessory nerves.

The minute structure of the central organs of the nervous system is excessively complicate and full of details. Hardening with chromic acid and bichromate of potash is generally advisable before examination. This should be done with small pieces in a large quantity of the fluid. One-eighth to one-half grain of bichromate, or 0.033 to 0.1 grain of chromic acid, to the ounce of water should be used, the strength gradually increased from day to day. After such maceration for several days, a drop of a 28 per cent. solution of caustic potash may be added to one ounce of water, and the specimen soaked in it for an hour, to macerate the connective tissue. After again soaking in graduated solutions of the bichromate, up to two grains to the ounce, the tissue may be carefully picked apart under the dissecting microscope. In such manner Deiters discovered the two kinds of processes in the multipolar ganglion-cells. Gerlach placed thin sections for two or three days in 0.01 to 0.02 per cent. solutions of bichromate of ammonia, and picked them apart after staining with carmine.

Lockhart Clarke placed parts of the spinal cord in equal parts of alcohol and water for a day, then for several days in pure alcohol, till thin sections could be made. These

were immersed for an hour or two in a mixture of one part acetic acid and three parts alcohol, to render the gray matter transparent and the fibrous elements prominent.

Sections may be stained with carmine and mounted in glycerin or balsam (see Chapter V).

(6.) Organs of special sense:

a. Organs of Touch.—The tactile papillæ of the skin and Pacinian corpuscles may be studied in thin sections of fresh or dried skin. Treatment with dilute acetic acid, or acetic acid and alcohol, and staining with carmine, or chloride of gold, is recommended. The papillæ are made up of connective tissue, into which nervous filaments enter, and end in peculiar tactile corpuscles (Plate XXIII, Fig. 173). The structure of the skin itself, with its various layers and sudoriparous glands, may be seen in such sections.

b. Organs of Taste.—The terminations of the gustatory nerves of the tongue are yet imperfectly known. In the circumvallate papillæ, on the side walls, certain structures are found, called *gustatory buds* or taste-cups (Plate XXIII, Fig. 174). They consist of flattened lanceolate-cells, arranged like the leaves of a flower-bud, and containing within them fusiform *gustatory cells*, which end in rods, and filaments projecting from the rods above the buds are seen in some animals. Underneath is a plexus of pale and medullated nerve-fibres. The mode of nervous termination in the fungiform papillæ is not known. For primary examination, sections of the dried tongue may be softened in dilute acetic acid and glycerin, or hardened in osmic acid. For the finer structure, maceration in iodine serum, and immersion in one-half per cent. chromic acid, with an equal quantity of glycerin, is recommended. Careful picking under the simple microscope is necessary. Sections may also be stained with chloride of gold.

c. Organs of Smell.—In the olfactory regions, which are patches of yellowish or brownish color on the upper and

deeper part of the nasal cavity, we find nucleated cylindrical cells taking the place of ordinary ciliated epithelium, and sending processes downward, which communicate with each other, forming a delicate network (Plate XXIV, Fig. 175). Between these cells we find the olfactory cells, spindle-shaped nucleated bodies, extending upward into a fine rod and downward into a varicose filament. In birds and amphibia these rods are terminated by delicate hairs, some of which have ciliary motion. Beneath these structures are peculiar glands, consisting of pigmented gland-cells. They are called Bowman's glands. The branches of the olfactory nerve proceed between these glands and branch out into fine varicose filaments, which are supposed to communicate with the olfactory cells. Hardening in chromic acid, or Muller's fluid, or a concentrated solution of oxalic acid, or one-half to one per cent. solution of sulphuric acid, is necessary for the preservation of these delicate structures.

d. Organs of Sight.—As in the sense of touch certain tactile papillæ detect deviations from the general surface; and in that of taste special rod-like end organs and their covering bulbs distinguish the solutions of different sapid substances; and as in smelling, not the whole organ but olfactory regions, with peculiar cells and nervous rods, discriminate mechanical or chemical odors, so in vision a special apparatus is provided to perceive the wonderful variety of colors and forms. The minute structure of organs becomes more complex in proportion as they serve the higher functions of mind.

The various tunics and accessory structures of the eye are described in most text-books; we here limit ourselves to a brief reference to those refracting and receptive structures whose office it is to translate the phenomena of light into those of nervous conduction.

Externally, we have in front of the eye the transparent *cornea*. This is made of connective tissue with cells, bun-

dles of fibres, and cavities containing cells. Its tissues are in layers, as follows: 1. External epithelium, flat and laminated. 2. Anterior basement-membrane or lamina. 3. True corneal tissue. 4. Membrane of Descemet or Demours. 5. Endothelium with flat cells (Plate XXIV, Fig. 17b). The cells of corneal tissue are of two forms. The first are wandering or amœboid cells, and may be seen in a freshly extirpated frog's cornea placed underside up, with aqueous humor in a moist chamber, on the stage of the microscope. If a small incision be made at the margin of the cornea of a living frog a few hours before its extraction, and vermilion, carmine, or anilin blue is rubbed in, the cells which have absorbed the coloring matter will be found at some distance afterwards, having wandered like leucocytes or pus-cells elsewhere. Their origin may be from blood or true corneal corpuscles, or both. The second form, or corneal corpuscles, are immovable, flat, with branching or stellate processes. They may be demonstrated by staining with chloride of gold or nitrate of silver. The bundles of fibrillar substance in the cornea pass in various directions, and the natural cavities in it contain the corneal cells. As stated, the nerves of the cornea have been traced to the external epithelium, which sometimes contains serrated (riff or stachell) cells.

The *aqueous humor* is structureless, but the *vitreous humor* is supposed to have delicate membranous septa. The *crystalline lens* consists of a capsule inclosing a tissue of fine transparent fibres or tubules, which are of epithelial origin. These fibres are flat, and often have serrated borders, especially in fishes.

The *retina*, or nervous portion of the eye, is the most important, as its delicacy and liability to decomposition render it the most difficult object of microscopic examination.

We must dismiss the popular notion of minute images

produced on the retina by the lens to be viewed by the mind. The lens does, indeed, form an image on the membrane, so it would on glass or paper, but the real action of the vibrations of light upon the nervous conductors is not thus to be explained.

The complex structure of the retina is only recently known, and it may be that many laws of light yet unknown are to be exhibited by its means, as well as much that relates to the connection of the perceiving thinking mind and the external world.

Muller's fluid, concentrated solution of oxalic acid, 0.6 per cent. solution of sulphuric acid, and 0.1 to 2 per cent. solutions of osmic acid, may be used for hardening, but very delicate dissection is required for demonstration. Rutherford recommends chromic acid and spirit solution, 1 gramme of chromic acid in 20 c.c. of water, and 180 c.c. of methylated spirit added slowly.

The retina consists of the following layers: 1. The columnar layer, or layer of rods and cones. 2. Membrana limitans externa. 3. External granular layer. 4. Intergranular layer. 5. Internal granular layer. 6. Molecular layer. 7. Ganglionic cell layer. 8. Expansion of optic nerve. 9. Membrana limitans interna. To these may be added: 10. The pigment layer, often described as the pigmented epithelium of the choroid, into which the rods and cones project. These layers are composed of two different elements, mutually blended, a connective-tissue framework of varying structure in the different layers, and a complex nervous tissue of fibres, ganglia, rods, and cones. Plate XXIV, Fig. 177, is a diagram of these separate structures, after M. Shultze, in Stricker's *Manual of Histology*.

The structure of the rods and cones is complex, and varies in different animals. The rods readily decompose, becoming bent and separated into disks, but examination of well-preserved specimens shows them to have a fibril-

lated outer covering. In addition, certain globular or lenticular refractive bodies, of different shape and color in different animals, are found in these structures (Plate XXIV, Fig. 178), which doubtless are designed to give the rays of light such a direction for final elaboration in the outer segment as they could not receive from the coarser refractive apparatus in the front of the eye.

e. Organs of Hearing.—These are most intimately connected with mental functions, because of language, which is the highest sensual expression of mind. Hence the structure of these organs is most delicate and complex.

The labyrinth is the essential part of the organ, consisting in man of the vestibule, the semicircular canals, and the cochlea. Sonorous undulations are propagated to the fluid in the labyrinth through the tympanum and chain of otic bones.

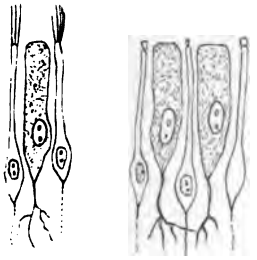
The auditory nerves are distributed to the ampullæ and sacculi of the vestibule, and to the spiral plate of the cochlea. At the terminal filaments in the sac of the vestibule, crystals, called *otoliths*, of shapes differing in various animals, are inclosed in membrane. Hasse considers them to be vibrating organs, but Waldeyer regards their function to be that of dampening sound.

As we distinguish in sounds the various qualities of pitch, intensity, quality, and direction, it is probable that there is a special apparatus for each, but histology has not yet established this fully. Kölliker thinks the ganglionic termination of the cochlear nerve renders it probable that it only receives sonorous undulations. The experiments of Flourens seem to show that the semicircular canals influence the impression of direction of sound.

In the sacs of the vestibule and ampullæ, the nerve-fibres are confined to a projection of the walls called the septum nerveum. Here are found cylinder- and fibre-cells, with rods, basal-cells, and nerves. But it is in the lamina spiralis of the cochlea that the most elaborate organ,

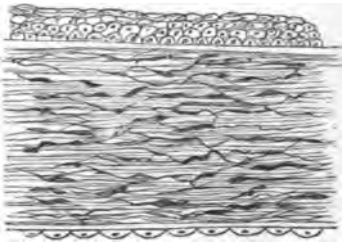
PLATE XXIV.

FIG. 175.



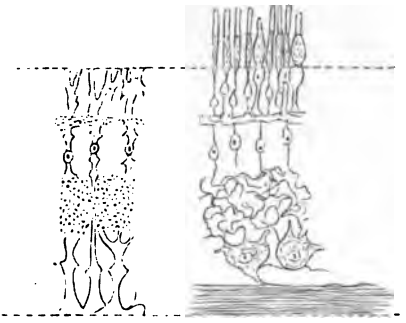
Olfactory cells.

FIG. 176.



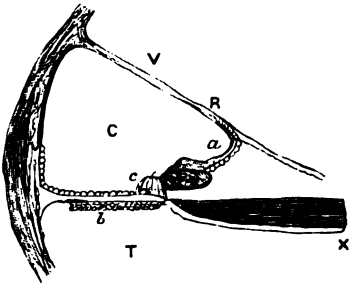
Section of Cornea.

FIG. 177.



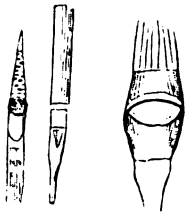
Connective-tissue and nerve-elements of Retina. Showing rods and cones.

FIG. 179.



Section of Cochlea:—V, scala vestibuli; T, scala tympani; C, canal of Cochlea; R, Reissner's membrane, attached at *a* to the habenula sulcata; *b*, connective-tissue layer; *c*, organ of Corti.

FIG. 178.

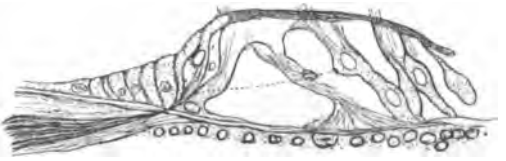


Refractive bodies in the rods and cones.

FIG. 180.

Corti's organ, from above.

FIG. 181.



Section of Corti's organ.

called from its discoverer the *organ of Corti*, is found. Kölliker considers the free position of the expanded portion of the nerve, and the extent of surface over which its terminal fibres are spread, to constitute it an organ of great delicacy, enabling us to distinguish several sounds at once and to determine their pitch. There is a striking analogy between the visual and auditory apparatus in the ganglionic structure of the nerve-structure. Plate XXIV, Fig. 179, represents a vertical section through the tube of the cochlea; and Plate XXIV, Figs. 180 and 181, the vestibular aspect and a vertical section of Corti's organ.

Waldeyer recommends examination of the cochlea in a fresh state and in aqueous humor. Preparations in osmic acid and chloride of gold are also useful. For sections he removes much of the bony substance of large cochleæ with cutting pliers, opens the membrane in several places, and places the specimen in 0.001 per cent. of chloride of palladium, or 0.2 to 1 per cent. osmic acid solution for twenty-four hours, then for the same time in absolute alcohol. It is then treated with a fluid composed of 0.001 per cent. chloride of palladium with one-tenth part of ¼ to 1 per cent. muriatic or chromic acid, to deprive it of earthy salts. It is then washed in absolute alcohol, and inclosed in a piece of marrow or liver, and placed to harden in alcohol again. The hollows of the cochlea may be filled with equal parts of gelatin and glycerin before they are inclosed. Sections must be cut with a sharp knife.

Rutherford advises the softening of the bone and hardening of other tissues by maceration in chromic acid and spirit (1 gramme of chromic acid in 20 c.c. of water, and 180 c.c. of methylated spirit slowly added). For sections he commends Stricker's mode of imbedding in gum. Place the cochlea in a small cone of bibulous paper, containing a strong solution of gum arabic, for four or five hours; then immerse the cone in methylated spirit for forty-eight

hours, or until the gum is hard enough. The sections may be stained with carmine, logwood, silver, or gold.

The following suggestions from Rutherford's *Outlines of Practical Histology*, will be of service to the student in this department:

Most of the tissues required may be obtained from the cat or guinea-pig. Feed the cat, and an hour or so after place it in a bag; drop chloroform over its nose until it is insensible. Open the chest by a linear incision through the sternum, and allow the animal to bleed to death from a cut in the right ventricle.

Divide the trachea below the cricoid cartilage and inject it with ¼ per cent. chromic acid fluid; tie it to prevent the escape of fluid, and place the distended lungs in the same fluid, and cover them with cotton-wool. Change the fluid at the end of eighteen hours. Allow them to remain in this fluid for a month, then transfer to methylated spirit till needed for mounting.

Open by a linear incision the œsophagus, stomach, large and small intestines, and wash them with salt solution (¾ per cent.). Place a portion of small intestine in chromic and bichromate fluid (1 gramme chromic acid and 2 grammes potassium bichromate in 1200 c.c. water) for two weeks (change the fluid at the end of eighteen hours), and then in methylated spirit till required. Act similarly with parts of œsophagus, stomach and large intestine, in ¼ per cent. chromic acid for three or four weeks. A portion of stomach may be placed in Muller's fluid till required for preparation of non-striped muscle, and of the gastric follicles.

The bladder may be treated as the small intestine.

Divide one kidney longitudinally, and the other transversely, and place in Muller's fluid. Change the fluid in eighteen hours, and after four weeks transfer to methylated spirits. They will be ready for use in two weeks after.

Cut one-half of the liver into small pieces and prepare as the kidneys. The tongue, divided transversely into five or six pieces, the spleen, uterus, and thin muscles from limbs or abdomen, in ¼ per cent. chromic acid. Change as before, and in a month to methylated spirit.

Testis of dog, freely incised, and ovaries of cat or dog, in Muller's fluid, and after three weeks to methylated spirits.

Divide the eyes transversely behind the lens. Remove the vitreous. Place posterior halves in chromic and spirit solution. Change in eighteen hours. Transfer to methylated spirit in ten days. Place the lens in Müller's fluid for five weeks, and then in methylated spirits. The cornea may remain in ¼ per cent. chromic acid for a month, and then in methylated spirit.

Cautiously open the cranial and spinal cavities. Remove brain and cord, and strip off arachnoid. Partially divide the cord into pieces a half inch long. Partially divide the brain transversely into a number of pieces. Place in a cool place in methylated spirits for eighteen hours. Transfer cord to ¼ per cent. chromic acid for six or seven weeks. Change in eighteen hours. Prepare the sciatic nerve in the same manner. Place the brain in chromic and bichromate fluid. Change in eighteen hours, and then once a week, until the brain is hard. If not leathery in six weeks place in ⅛ per cent. chromic acid for two weeks, and then in methylated spirits. Support the brain and cord on cotton-wool in the hardening fluid.

Remove muscles, but not periosteum from bones of limbs, and both from the lower jaw. Divide the bones transversely in two or three places, and put them in chromic and nitric fluid (chromic acid, 1 gram; water, 200 cc.; then add 2 cc. nitric acid). Change the fluid often until the bone is soft enough, and transfer to methylated spirits. If not complete in a month, double the quantity of nitric acid in the fluid.

Place a piece of human scalp, skin from palmar surface of finger, and skin of dog (for muscles of hair-follicles) in chromic and spirit fluid. In a month transfer to methylated spirit.

Remove the petrous portion of temporal bone, open the tympanum, pull the stapes from the oval fenestra, and place the cochlea in chromic and spirit fluid. Change in eighteen hours, and at the end of seven days, if a brown precipitate falls, change fluid every third day. On the tenth or twelfth day transfer to chromic and nitric fluid. Change frequently till the bone is soft. Then place it in methylated spirit. The cochlea of the guinea pig projects into the tympanum, and is, therefore, convenient for enabling the student to see how the cone is to be sliced when sections are made.

Too long exposure to chromic acid renders tissues friable, and prevents staining with carmine.

Methylated spirit is ordinary alcohol containing 10 per cent. of wood-naphtha, and is used in England as a substitute for alcohol, since it is free of duty for manufacturing purposes.

CHAPTER XIII.

THE MICROSCOPE IN PATHOLOGY.

Pathological histology treats of the minute anatomy of the tissues and organs in disease, and is essential to a knowledge of structural changes in the body. Since the old method of judging solely by symptoms has given place to the more rational observation of the actual changes produced, the microscope has become an indispensable aid to practical medicine. As anatomy would be coarse and imperfect without histology, so pathological histology

perfects pathology, and guides to right conclusions the seeker after positive truth in medicine.

Our plan forbids an extensive outline of the facts of morbid anatomy. We propose merely such a classification of the microscopic appearances of diseased structures as may serve to guide the student and busy practitioner in actual observation.

PREPARATION OF SPECIMENS.

Much may be learned by the examination of a pathological specimen without any preparation whatever, or with the use of indifferent fluids (see Chapter V). A thin section may be made under water with a Valentin's knife, or a small portion may be snipped off with curved scissors and teased with fine needles. The freshly-cut surface of tumors may be gently scraped with a knife and the separated elements examined in glycerin and water.

For a thorough examination it will be necessary to harden, stain, and make thin sections, as described in Chapter V and at page 224. Müller's fluid, page 68, will be found most generally useful for morbid specimens. After small pieces have lain some time in this they can be still further hardened by absolute alcohol. Before cutting thin sections, either by hand or with a section-cutter, the specimen will require to be imbedded so as to be readily held and cut without tearing. A mixture of wax or paraffin and olive oil is generally used of such consistence as will indent readily with the thumb-nail when cold. For very delicate tissues, saturation in a mixture of glycerin and gum arabic, made perfectly clear and viscid, so as to be easily drawn out into threads, is useful. After saturation the specimen is thrown into alcohol, which hardens the gum and fixes the tissues so as to be readily cut. The thin section can be thrown into water, or carmine solution, to dissolve the gum, and the stained

preparation can be mounted in glycerin, balsam, or dammar (Chapter VI). In fixing the cover to specimens mounted in glycerin it may be useful to apply liquid glue or strong gelatin solution to the edges, using the turntable or otherwise, and after it is dry to cover it with some other cement. Any glycerin which may accidentally be on the cover had better be left until the glue has dried, when it can be removed by a camel's hair brush and water.

Dr. Beale recommends that nitrate of silver, chloride of gold, osmic acid, etc., when used for staining fine tissues, should be dissolved in glycerin. Less than ½ per cent. solution of gold, etc, will thus bring out details which are scarcely attained otherwise. The time of soaking and strength of the solution varies according to the tissue and effect desired.

The most delicate sections are made by freezing specimens after they have been well saturated with a strong solution of gum arabic. For this purpose Professor Rutherford's freezing microtome has been invented, in which the cylinder of the ordinary section-cutter, page 63, is surrounded by a reservoir for powdered ice and salt, so as to freeze the tissue. Dr. Beale recommends freezing by the use of nitrous oxide gas, and Dr. Pritchard has suggested a metallic cylinder with a wooden handle, which can be cooled below the freezing-point by salt and ice. A small piece of tissue will immediately freeze on the metal so as to be cut into thin sections by hand. If thawing sets in it may be covered with thin gutta-percha and plunged into the ice and salt.

Dr. S. Marsh, in an excellent little treatise on section-cutting, recommends that the knife should not be ground flat on one side, but be slightly concave on each side. In cutting it is necessary to keep the blade well flooded with spirit, except in using the freezing microtome. The sections are best transferred to a basin of water, and lifted

to the staining fluid, etc., not with a camel's hair brush, but with a little slip of tin, copper, etc., with a bent and perforated end, making a sort of lifter or flat spoon. In making sections, either by hand or with the section-cutter, the razor or knife must be kept always sharp, and drawn from heel to point so as to cut with a single stroke the thinnest possible slice.

THE APPEARANCE OF TISSUES AFTER DEATH.

Formation and decomposition, or progression and retrogression, coexist in most morbid structures, so that it is necessary for the student not only to be familiar with normal histology, but also with the products of decay and death and the varied appearances in disease.

The death of the individual parts of the organism is called *necrosis*, mortification, or gangrene. Various changes follow it, depending chiefly on moisture, producing dry or moist gangrene.

Necrosis depends on the cessation of the nutritive process from abolition of the normal supply of blood, or from mechanical or chemical violence.

Living tissues bathed in suitable fluids dissolve albuminates and their derivatives, but when life departs they no longer withstand solution themselves.

1. *Protoplasm.*—It has been shown, page 118, that the term bioplasm has been appropriated to elementary or germinal structure during life, and at page 188 we regarded the leucocytes, or white corpuscles of the blood, chyle, etc., as simply bioplasts. After death, or in order to designate their physical constitution, the most suitable term for them is protoplasm. In necrosis this colorless protoplasm dissolves after slightly swelling, and entirely disappears.

2. *Blood.*—Decomposes very rapidly. The coloring matter leaves the red corpuscles and is diffused through

the tissues (hence the dark color of a scab), then the corpuscle disintegrates and breaks up into granules. Sometimes there is found an aggregation of brownish-colored blood-corpuscles undergoing disintegration at the edges as in Fig. 182.

FIG. 182.

The gangrenous disintegration of tissues. *a.* Aggregation of blood-corpuscles. *b.* Smooth muscular fibres. *c.* Striated muscular fibres. *d.* Breaking up of same into Bowman's disks. 1-300.—After RINDFLEISCH.

3. *Nucleated Cells.*—In these the protoplasm coagulates, forming a solid albuminate, which becomes cloudy and breaks up into granules.

4. *Cell membrane* resists decomposition in proportion as it has become horny. Hence the outer layers of epithelium last longer than the inner ones.

5. *Smooth Muscular Fibre.*—Minute dusty granulations first make their appearance, which unite so that the fibre seems transversely striated. As decay goes on the muscle changes into a slimy granular substance which may be drawn into threads.

6. *Striated Muscular Fibre.*—The muscle-juice coagulates to a solid albuminate, giving rise to rigor mortis in from twelve to fourteen hours after death, except in death from charcoal or sulphuretted hydrogen vapor, lightning, or from putrid fevers, or long debility. This stiffness of muscle lasts about twenty-four hours. In the necrosed fibres under the microscope the transverse striæ and nuclei disappear amid a cloud of minute granulations, then fat-globules and reddish pigment-granules show themselves, the fibres melt away from the edges and become gelatinous. If gelatinous softening is marked the fibres may disintegrate into Bowman's disks, or disks produced by transverse cleavage (Fig. 182).

7. *Nerve-tissue.*—Little is known of the process of de-

cay in nerves save that the thicker nerve-trunks maintain themselves for a comparatively long time, while the finer ramifications soon dissolve. The white substance of Schwann (page 199) first coagulates, then there is a collection of drops of myelin within the neurilemma, producing varicosity before complete dissolution.

8. *Adipose Tissue.*—The fluid fat leaves the cells and gives an appearance of emulsion to the mass. Crystals of margarin, etc., sometimes appear on the cell-walls.

9. *Loose connective tissue fibres* swell, become stained with the coloring matter of blood, granulate, and liquefy; or they may desiccate by evaporation.

10. *Elastic fibres and fibrous networks* resist longer than the last. Hence, elastic fibres may be found in expectorated matter from gangrenous lungs, etc. Later they break into granular striæ, then into molecules and vanish.

11. *Cartilage* lasts long, but melts away at the edges, first becoming transparent and reddish. The cells fill with fat-globules from fatty degeneration of the bioplasm.

12. *Bone* retains its structure long, so as to be recognized by the surgeon in sequestræ, yet it decays in patches. The bioplasm changes to fat in the cells, acid fluids dissolve the lime salts, and the remaining structure disintegrates like cartilage.

FIG. 183.

Products of gangrenous disintegration. *a.* Leucin; *b.* Tyrosin; *c.* Fat-crystals; *d.* Ammoniaco-magnesian phosphate; *e.* Gangrene particles (black pigment); *f.* Vibriones. 1-300.—After RINDFLEISCH.

The chemical products of decomposition are but partially known. Some are volatile, some soluble in water,

and others more solid, producing a new series of microscopic objects after the disappearance of the histological forms (Fig. 183).

Leucin (Fig. 183, *a*) forms partly homogeneous drops or globules, partly bodies of concentric layers, and partly stellate spheres of minute crystalline needles.

Tyrosin (*b*) generally found along with leucin, forms satiny white needles, isolated, or in sheafs or rosettes.

Margarin (*c*) a mixture and crystalline separation of the solid fats, stearin, and palmitin, occurs quite frequently.

Ammoniaco-magnesian phosphate (*d*) is only found in alkaline or neutral ichor.

Pigment-bodies (*e*) are very small, and have a variety of forms. As characteristic of necrosis the small, black, irregular particles, resisting most reagents, must be distinguished from hæmatin pigments, though they are probably identical with melalin.

Living Organisms (*f*).—In addition to minute fungi, or moulds (aspergillus, oidium, etc.), vibriones are quite common. Pasteur regards them as the visible elements of decay (see page 135).

DEGENERATION OF TISSUES.

Degenerations are usually divided into two classes, true degenerations, or metamorphoses, and the infiltrations.

1. The true degenerations or metamorphoses are characterized by the direct change of the albuminoid constituents of the tissues into new material. The metamorphoses include fatty, mucoid, and colloid degenerations.

2. The infiltrations differ from the true degenerations, since the new material which exists in the tissues is not derived from their albuminoid constituents, but is deposited in them from the blood. The anatomical characters are much less altered than in the metamorphoses,

and function is usually less interfered with. They include fatty, amyloid, calcareous, and pigmentary infiltration, etc.

THE METAMORPHOSES.

1. *Fatty Degeneration.*

The metamorphosis of the protoplasm of the cell is marked by the occurrence of fat-globules in its interior. Its progress may be illustrated by degenerating epitheliun in dropsy of the pericardium (Fig. 184).

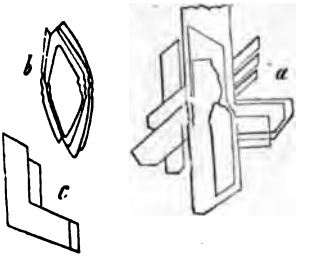
FIG. 184.

The fatty metamorphosis. Epithelium of the pericardium in dropsy of pericardium. *a*. Cells which still show the normal form and arrangement. First appearance of fat-globules. *b*. Granular globules, the one with a nucleus still visible. *c*. Granular globules disintegrating to fatty detritus.—After RINDFLEISCH.

The granular corpuscles were formerly known as the "inflammatory" or "exudation corpuscles," or "corpuscles of Gluge." They are identical in structure with colostrum-corpuscles thrown off by the mammary gland after parturition, and the last act of fatty degeneration is considered as a *lactification*. The fatty detritus may be absorbed as milk, or if not absorbed it is partly saponified and partly separated in solid form, as margarin, etc. Finally there is an abundant deposition of crystals of cholesterin (Fig. 185).

This substance is found normally in the brain and spinal marrow in quite large proportions, and in solution in the bile. It forms rhombic tablets, lying in heaps, with their long sides parallel.

FIG. 185.



Crystals of cholesterin.—After VIRCHOW.

In some cases when the fatty detritus is not absorbed it undergoes a change into a crumbling material somewhat resembling cheese, and hence called *caseation*. This ap-

pears to be owing to desiccation of the substance from deficient vascular supply. It is most frequent in parts which contain but few vessels, or in those in which the vessels are obliterated by new growths. It was formerly believed to be the product of tuberculosis, and regarded as the separation of morbid matter (crude tubercle) from diseased blood. Tubercle may undergo fatty degeneration and caseation, but it is by no means true that all cheesy masses are tubercular.

Fatty degeneration in the arteries may be illustrated by *atheroma*, beginning as a fatty metamorphosis of connective tissue, and ending in calcification or impregnation with lime salts. In the fibres of *voluntary muscle* the albuminous matter of the fibre is converted into fat, which is seen in rows of minute globules, like strings of pearls in the long axis of the primitive bundles, while the transverse striæ become indistinct (Fig. 186).

FIG. 186.

Fatty degeneration of striated muscular fibres. 1-300.—After RINDFLEISCH.

In advanced stages of infantile spinal paralysis, perhaps from inaction as well as innutrition, the atrophied muscles are subject to fatty degeneration, which may be observed by removing small portions of muscular tissue by Duchenne's trocar, a sort of double needle, one part of which slides upon the other, jutting against a steel shoulder, so as to catch and detach a small piece from a muscle into which it is inserted. A microscopic examination of the detached fibre will show the amount of degeneration, and thus from time to time the progress of disease or the effects of treatment may be noted.

In *pulmonary emphysema* the epithelium is so changed by fatty degeneration that the degenerated elements are better seen than the normal (Fig. 187).

Softening of the brain, as it is termed, is largely due to fatty degeneration. Whatever interferes with nutrition, by preventing a proper supply of blood, will produce fatty degeneration and softening. Acute cases may be produced by embolism or thrombosis. *White softening* is generally a chronic condition of old age, and owes its

FIG. 187.

From the inner surface of a larger emphysema vesicle. Fatty remains of the lung-tissue, containing elastic fibres, smooth muscular fibres, and covered with fatty degenerated epithelia. 1-500.—After RINDFLEISCH.

color to the gradual diminution of blood-supply. *Yellow and red softening* depend on larger proportions of blood-pigments. A vertical section of a specimen of yellow softening shows accumulations of fatty granules between the nerve-fibres, and their formation into larger granular corpuscles (Fig. 188).

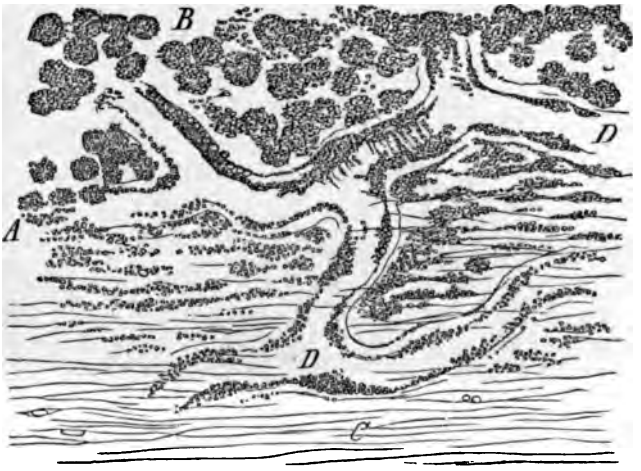
2. *Mucoid Degeneration.*

This is a transformation of albuminoid tissues into *mucin*, a material of a soft jellylike consistence. This is

the embryonic condition of most tissues, and in the umbilicus and the vitreous humor of the eye this character persists after birth.

The mucus which normally covers the mucous membranes is largely, if not wholly, derived from the swelling and softening of epithelial cells, but in mucoid degen-

FIG. 188.



Yellow softening of the white substance of the brain. *A*. Border of the depot of softening, *B*, and of the brain-substance, *C*, not yet softened. *D*. A fatty degenerated vessel. 1-300.—After RINDFLEISCH.

eration the change chiefly pertains to the intercellular elements. Thus cartilage softens (Fig. 189).

The matrix first exhibits striæ which afterwards split into fibres. The ends of the fibrils taper to a point and are dissolved by mucoid metamorphosis. In bone the solution of the lime salts and the liquefaction of the basis-substance are generally simultaneous, but in some cases, as in Fig. 190, the difference between the two is quite apparent.

3. *Colloid Degeneration.*

In this the cells, rather than the intercellular structure, are especially involved. Colloid resembles mucin in ap-

pearance, but unlike it contains sulphur and is precipi-

FIG. 189.

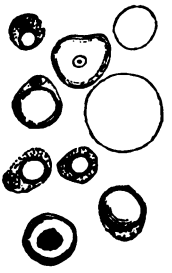
Softening of cartilage. Vertical section of an articular cartilage in malum senile articulorum. 1-300.—After RINDFLEISCH.

FIG. 190.

Softening of bone. Fragment of bone from the spongy substance of an osteomalacious rib. *a*. Normal osseous tissue; *b*. Decalcified osseous tissue; *c*. Haversian canals; *d*. Medullary spaces; *d**. A medullary space filled with red medulla. 1-300.—After RINDFLEISCH.

tated by acetic acid. It resembles jelly or half-set glue. It first appears as a small globule in the cell, which grows, pushing aside the nucleus, until it not only fills the cell but swells largely, communicating with neighboring cells so as to form cystlike cavities containing the gelatinous substance. Here it may afterwards undergo liquefaction (Fig. 191).

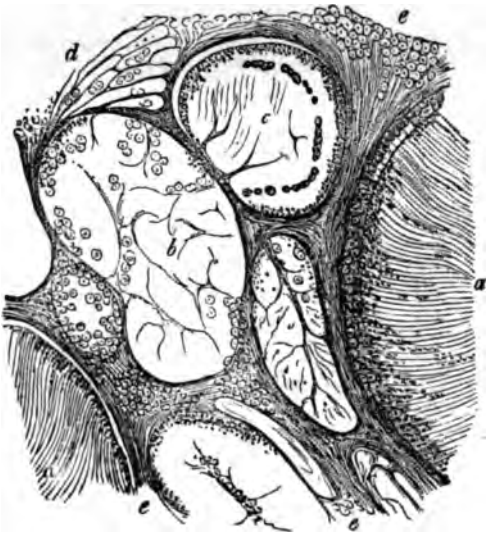
FIG. 191.



Colloid degenerating cells from a colloid cancer—After RINDFLEISCH.

The colloid change is most common in enlargements of the thyroid gland, in the lymphatic glands, and in many of the new formations. Colloid or mucoid tumors, or tumors which have undergone these forms of transformation, are some-

FIG. 192.



Colloid degeneration in the stroma of an ovarian cystoid. *a, a.* Larger cysts, whose walls bear an incomplete epithelium of low cylindrical cells whose contents after hardening is split up radiating. *b.* Younger cysts without epithelium permeated by remains of connective tissue fibres. *c.* The same with a wreath of loose epithelia *d.* Colloid infiltration of the connective tissue which has not yet attained any cystoid appearance and inclosure. *e.* Small-celled infiltration of the stroma. 1-200.—After RINDFLEISCH.

times called colloid cancers, when their structure may be altogether different from cancer.

Some forms of multilocular ovarian cysts depend, according to Rindfleisch, upon a colloid degeneration of the stroma of the ovary, wherein an epithelial proliferation furnishes the foundations of the cysts. Such a case may be termed a cystic colloid cancer of the ovary (Fig. 192).

THE INFILTRATIONS.

1. *Amyloid Infiltration.*

This is known also as lardaceous or waxy degeneration and vitreous swelling. It consists of the infiltration of some sort of albuminate from the blood, which is characterized by its becoming brownish-red or violet color by treatment with iodine. It sometimes exhibits concentric layers, like starch, which with the color phenomena led Virchow to call it amyloid.

The amyloid infiltrated cell (Fig. 193) is distinguished from the normal by its greater circumference, together

FIG 193

Amyloid infiltrated liver-cells. *a*. Isolated cells. *b*. A fragment of the liver-cell network, in which the dividing lines of the individual cells are no longer visible. 1-800. —After RINDFLEISCH.

with a certain rounded irregularity. If several are in contact they often coalesce into elongated lumps, in which the individual elements connot be recognized.

The walls of small arteries and capillaries are the first to be attacked in all infiltrations, and this is especially observable in amyloid infiltration. Fig. 194 represents partial amyloid infiltration of a Malpighian tuft of the kidney. The blue injection, and of course the blood dur-

ing life, penetrates only the capillary loops which are free from deposit. The addition of iodine, staining the amyloid matter red, gives an alternation of blue and red loops.

FIG. 194.

Amyloid infiltrated Malpighian vascular coil of the kidney. 1-300.—After RINDFLEISCH.

Amyloid infiltration impairs the nutrition of a part both by the obstruction of the circulation and by its direct influence. Hence atrophy and fatty metamorphosis are often found associated with it.

In lardaceous liver, or *amyloid infiltration of the liver*, the minute branches of the hepatic artery are first affected, then the region of the hepatic vein, and afterwards the

FIG. 195.

Amyloid liver. *A*. Interlobular artery with amyloid walls. *G, G*. Biliary ducts. *p, p*. Portal vessels. *V, V*. Interlobular veins. The liver-cells in the central zones of the acini are infiltrated with amyloid substance. 1-300.—After RINDFLEISCH.

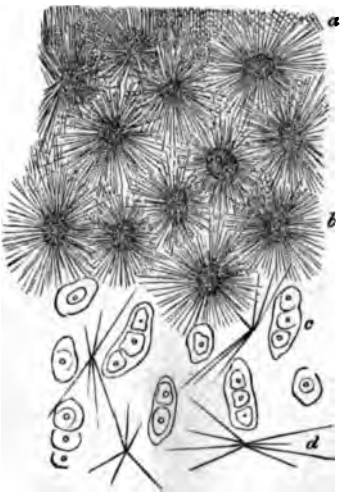
hepatic cells in the region of the portal vein, until the whole organ may ultimately have twice as much solid albuminous substance as normal, and becomes pale gray in color, translucent, and of waxlike consistence (Fig. 195).

2. *Calcification.*

Calcification is the infiltration of tissue with solid phosphate or carbonate of lime. Free carbonic acid is solvent of these salts, and by its capacity for diffusion it escapes, leaving the insoluble salts in the nutritive fluid.

Thus cartilage normally becomes bone, and under peculiar circumstances other tissues ossify. True osseous tissue, however, differs greatly from mere calcification by

FIG. 196.



Arthritis uratica. Vertical section through a superficial articular body infiltrated with urate of lime. *a*. The surface. *b*. Cartilage cavities with tufts of crystals. *c*. Cartilage cells not yet infiltrated, in division. *d*. Isolated needles of crystals in the basis-substance. —After CORNEIL ET RANVIER.

the arrangement of its solid particles (see page 195). Calcification of arteries is a secondary affection, succeeding to fatty degeneration of the connective tissue.

Analogous to calcification is the *arthritic deposit* of

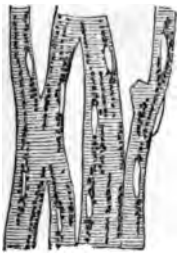
urates into articular cavities, and the parenchyma of the cartilage, bones, and membranes of the joints of gouty persons. It is most common in the cartilage cells (Fig. 196).

The uric acid infiltration acts as a mechanico-chemical agent to the affected parts, producing œdema, suppuration, caries, etc.

3. *Pigmentation.*

All true pigments are derived from the coloring matter of the blood. Many of them are eliminated by the kidneys and liver, but some are deposited in the tissues, as the choroid coat of the eye and the rete Malpighii of the skin. Some pathological cases may be ascribed to extravasation or some local stasis in the circulation; others may be caused by wandering leucocytes (page 188). The brown atrophy of the muscular tissue of the heart, which is often associated with marasmus, is caused by the deposit of yellow granular pigment in the muscular fibre (Fig. 197).

FIG. 197.



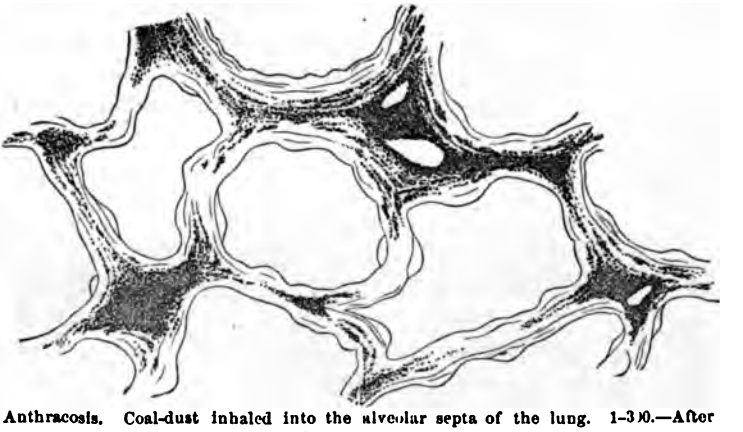
Brown atrophy of heart-muscle. Fragment of a membrane of muscular fibres, with pigment-granules in the interior of the primitive bundles. 1-300. — After RINDFLEISCH.

The dark pigment of the lungs owes its origin chiefly to the respiration of carbon in the shape of particles of soot, coal-dust, etc., floating in the atmosphere. These particles are first taken up by the mucous corpuscles (leucocytes) of the trachea and bronchi, and many of them are expectorated. Some, however, make their way to the air-vesicles, and penetrate the alveolar walls and interlobular tissue (Fig. 198).

In the case of coal-miners the lungs often become uniformly black. Workers in iron-dust are liable to have the lungs stained red from oxide of iron, and stonecutters, etc., to inhale and deposit silicic acid or fine sand. Such

particles produce irritation and inflammatory phenomena, accompanying which is a formation of true pigment from the blood, whose deposit increases the darkness of tint in

FIG. 198.



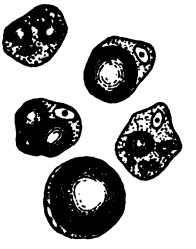
Anthracosis. Coal-dust inhaled into the alveolar septa of the lung. 1-300.—After RINDFLEISCH.

the lungs. Many morbid conditions, also, are attended with formation of pigment.

4. *Fatty Infiltration.*

In this form of degeneration the fat is derived from the food, and must be distinguished from that metamorphosis called fatty degeneration. In fatty infiltration the fat occurs in the cells as distinct drops of oil (Fig. 199).

FIG. 199.

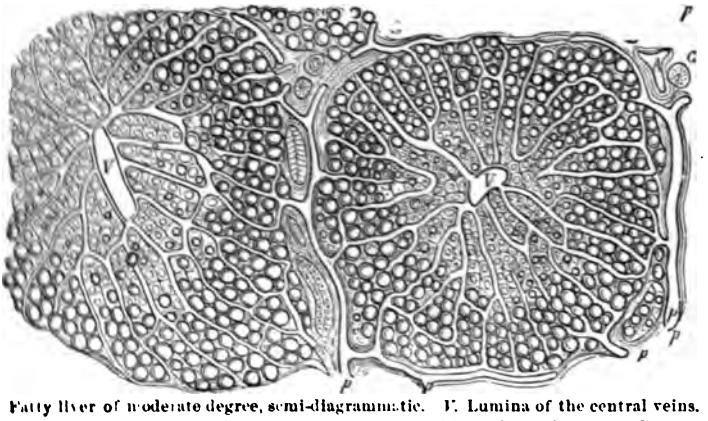


Fatty infiltrated liver-cells. 1-300. — After RINDFLEISCH.

The vitality and functions of the cells are but little impaired by the accumulation, which may be again reabsorbed, while in fatty metamorphosis the elements are destroyed. Fatty infiltration of muscle is seen in the connective tissue between the fasciculi, and not in the muscular fibres themselves as in fatty degeneration.

The "fatty liver," as it is called, is due to infiltration. The ingestion of fatty aliments is followed by temporary accumulation of fat in the portal blood, which is apt to be deposited in the portal capillaries of the liver, which is gradually conveyed to the central or hepatic capillaries of the lobules, and thus to the general circulation. In morbid conditions, as in tuberculosis and heart disease, we find the morbidly fatty liver first infiltrated in the portal zone as in Fig. 200.

FIG. 200.



Fatty liver of moderate degree, semi-diagrammatic. *V.* Lumina of the central veins. *p* Interlobular branches of the vena portæ. *A.* Arterial branches. *G.* Biliary ducts.—After RINDFLEISCH.

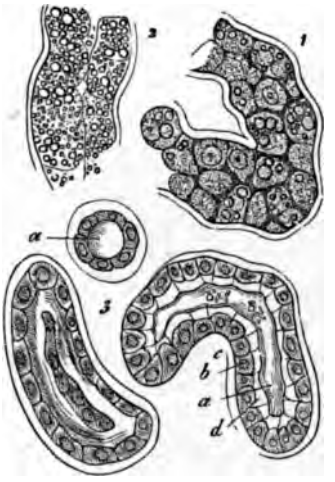
In more advanced cases all the liver-cells become filled and the bounds of the acini are effaced. Fat may occur in the liver in connection with general obesity, or from a failure of the oxygenating power of the blood, in which case there may be general emaciation.

5. *Albuminous Infiltration.*

Albuminous infiltration, or cloudy swelling, consists in filling the tissues with molecular albumen. It is regarded by Virchow as a nutritive irritation, or an incitation of

cells to take up an abnormal amount of nutritive material. It occurs after local and general irritations, which bring to the part an increased supply of blood, and is especially important in the muscles and the large glands, as the liver and kidneys. In the latter it is often associated with fatty degeneration and fibrinous exudation, as in Fig. 201.

FIG. 201.



1. Cloudy swelling and commencing fatty degeneration of the epithelia of the convoluted urinary tubuli. 2. Advanced fatty degeneration. 3. Formation of fibrinous cylinders. *a*. Cross-cut of a urinary tubulus, with a gelatinous cylinder filling the lumen. *b*. Epithelium. *c*. Tunica propria. *d*. Renewed production of colloid at the surface of the epithelial cells, which elevates the older. 1-500.—After RINDFLEISCH.

6. *Serous Infiltration.*

This is an infiltration of the tissues with a serous or sero-mucous substance producing œdema, and seems analogous to mucoid degeneration. Under the microscope bright spots appear in various cells, of which Wagner declares it to be uncertain whether they are artificial or diseased products, and if the latter, whether they are serous, mucous, or colloid.

INFLAMMATION.

Inflammation is a complex process, beginning with an increased flow of blood into or towards the part affected, and generally leading to exudation or suppuration, sometimes healing by resolution or leading to new formations, to various metamorphoses, or to destruction of tissues, with a disturbance of the function of the part affected.

Inflammation of the various tissues or organs are distinguished by adding the termination *itis* to the Latin or Greek term, as encephalitis, pleuritis, nephritis, etc.; or a special name is given, as pneumonia, for inflammation of the lungs, erysipelas, for inflammation of the skin, etc.

Inflammations of serous coverings of organs receive the prefix *peri*, as perihepatitis, perimetritis, etc. (except peribronchitis, and periphlebitis, which refer to inflammation of the exterior of the bronchial or venous wall). Inflammations of the surrounding connective tissue or appendages of an organ are known by the prefix *para*, as paranephritis, paracystitis, parametritis, etc.

Inflammation is the result of some kind of injury to the tissue affected, either direct, as from mechanical or chemical agents, or indirect, as from specific contagions, exposure to cold, etc.

The first phenomenon of inflammation is congestive hyperæmia, or an increased flow of blood. There is first a dilatation of the vessels, with an acceleration of the current, which is soon followed by a retardation of the current, producing stagnation or cessation of circulation. Several theories have been advanced to explain this phenomenon. According to the paralytic theory the irritation affects only the sensitive nerves, *e. g.*, of the skin, and produces an antagonistic paralysis in the vasomotor nerves. The vessels then relax, dilate, and receive more blood. According to Virchow and Beale, it is the cell in

itself without the intervention of the nerves or the blood, which is excited to increased nutritive activity, to greater metamorphosis, and to new formation; and the more quickly this takes place, the more it runs the danger of destruction, the more is the process to be looked on as inflammatory. There may be truth in both these views, since the nutrition of the cell is so greatly influenced by nerve action.

The second phenomenon of inflammation is exudation and suppuration. The most disputed point respecting inflammation has been the genesis of pus-corpuscles. We have seen, page 189, that they are identical in the living state with leucocytes, or white blood-cells. In other words, they are merely particles of bioplasm. Their migration

FIG. 202.

Cohnheim's experiment. *a*. Vein. *b b*. Contiguous connective tissue, permeated by migrating colorless blood-corpuscles. *c*. Column of red blood-corpuscles. 1-500.—After RINDFLEISCH.

through the walls of bloodvessels was first described by Dr. Addison in 1842, and afterwards, in 1846, by Dr. Waller. These observations were forgotten, however, until 1867, when Professor Cohnheim, of Berlin, showed the

importance of this migration to the pathology of inflammation. His experiment consisted in stretching the mesentery of a living frog, paralyzed by the subcutaneous injection of $\frac{1}{8}$ per cent. solution of curare, over a ring of cork, and placing it under the microscope. The veins are seen to dilate, and the colorless blood-corpuscles first cling to the inner surface of the wall of the vessel, then a process from the bioplast passes through the wall, which swells up outside, and in this way a bridge is formed upon which the whole substance of the cell creeps over. By their amœboid motions the cells wander further, and accumulate at the irritated part of the tissue which becomes the point of departure for future changes (Fig. 202).

Stricker has shown, by experiments on the tongue and cornea of the frog, that the migratory cells, or pus-corpuscles, in inflammation increase by division.

Dr. Beale holds the opinion that although some of the pus-corpuscles may be derived from the division of colorless blood-cells, yet the great mass of them results from the bioplasts of the tissues in which the pus-formation takes place. In this he follows the earlier teaching of Virchow, which supplanted the older view that pus-corpuscles originated in a structureless exudation. Dr. Beale recommends the examination of a portion of cuticle raised by a small blister, which may be stained with carmine, or examined fresh in the serum of the blister. The bioplasm of the inflamed epithelial cells will be found larger than in the normal state, and in some instances will be seen to project beyond the formed material of the cells, and the free portions divide and subdivide in the exudation poured out from the bloodvessels.

In Chapter IX we have referred to Dr. Beale's views respecting the elementary histological unit or cell, which seem to agree with the phenomena recorded by Max Schultze, Cohnheim, Stricker,* etc. So influential have

* Stricker's Manual of Histology, chap. i.

been these views in pathology, that we quote from him the following abstract concerning the changes in the cell in disease:

"Of the different constituents of the fully formed cell, the germinal matter is alone concerned in all active change. This is, in fact, the only portion of the cell which lives, while at an early period of development the parts of the cell usually regarded as necessary to cell existence are altogether absent. The 'cell' at this period is but a mass of living germinal matter, and in certain parts of the body, at all periods of life, are masses of germinal matter, destitute of any cell-wall, and exactly resembling those of which at an early period the embryo is entirely composed. White, blood, and lymph corpuscles, chyle corpuscles, many of the corpuscles in the spleen, thymus, and thyroid, corpuscles in the solitary glands, in the villi, some of those upon the surface of mucous membranes, and minute corpuscles in many other localities, consist of living germinal matter. There is no structure through which these soft living particles may not make their way. The destruction of tissue may be very quickly effected by them, and there is no operation peculiar to living beings in which germinal or living matter does not take part. Any sketch of the structure of the cell would be incomplete without an account of some of the essential alterations which take place in disease, and it is therefore proposed to refer very briefly to the general nature of some of the most important morbid changes.

"If the conditions under which cells ordinarily live be modified beyond a certain limit, a *morbid* change may result. For instance, if cells, which in their normal state grow slowly, be supplied with an excess of nutrient pabulum, and increase in number very quickly, a *morbid* state is produced. Or if, on the other hand, the rate at which multiplication takes place be reduced in consequence of an insufficient supply of nourishment, or from other causes,

a diseased state may result. So that, in the great majority of cases, disease, or the morbid state, essentially differs from health, or the healthy state, in an increased or reduced rate of growth and multiplication of the germinal matter of a particular tissue or organ. In the process of inflammation, in the formation of inflammatory products, as lymph and pus, in the production of tubercle and cancer, we see the results of increased multiplication of the germinal matter of the tissues or of that derived from the blood. In the shrinking, and hardening, and wasting which occur in many tissues and organs in disease, we see the effects of the germinal matter of a texture being supplied with too little nutrient pabulum, in consequence sometimes of an alteration of the pabulum itself, sometimes of an undue thickening and condensation of the tissue which forms the permeable septum intervening between the pabulum and the germinal matter.

"The above observations may be illustrated by reference to what takes place when pus is formed from an epithelial cell, in which the nutrition of the germinal matter, and consequently its rate of growth, is much increased. And the changes which occur in the liver-cell in cases of cirrhosis may be advanced in illustration of a disease which consists essentially in the occurrence of changes more slowly than in the normal condition, consequent upon less than the normal freedom of access of pabulum to the germinal matter.

"The outer hardened formed material of an epithelial cell may be torn or ruptured mechanically, as in a scratch or prick by insects, or it may be rendered soft and more permeable to nutrient pabulum by the action of certain fluids which bathe it. In either case it is clear that *the access of pabulum to the germinal matter is facilitated*, and the latter necessarily 'grows'—that is, converts certain of the constituents of the pabulum that come in contact with it into matter like itself at an increased rate. The

mass of germinal matter increases in size and soon begins to divide into smaller portions. Parts seem to move away from the general mass. These at length become detached, and thus several separate masses of germinal matter, which are imbedded in the softened and altered formed material, result. In this way the so-called inflammatory product *pus* results.

"It will be seen how easily the nature of the changes occurring in cells in inflammation can be explained if the artificial nomenclature of cell-wall, cell-contents, nucleus be given up. In all acute internal inflammations a much larger quantity of inanimate pabulum is taken up by certain cells and converted into living matter than in the normal state. Hence there is increase in bulk; cells of particular organs, which live slowly in health, live very fast in certain forms of disease. More pabulum reaches them, and they grow more rapidly in consequence.

"In cells which have been growing very rapidly and are returning to their normal condition, *in which the access of nutrient pabulum is more restricted than in the abnormal state*, as is the case in normal cells passing from the embryonic to the fully formed state, the outer part of the germinal matter undergoes conversion into formed material, and this last increases as the supply of pabulum becomes reduced.

"We will now inquire what alterations can be observed in cells, the '*formed material*' of which, under *normal conditions*, becomes *quickly* resolved into other soluble constituents if these cells be placed under circumstances which caused the formed material to become harder and less permeable to nutrient matter than in health. The formed material which enters into the formation of the liver-'cell' is soft, moist, and readily permeable to certain nutrient matters. There is no cell-wall, but the outer part of the formed material is gradually resolved into soluble biliary matters, which pass down the ducts, and

Contraction and condensation of the liver, kidney, and other glands, hardening, shrinking, and wasting the muscular, nervous, and other tissues, are good examples of the second. The amount of change becomes less and less as the morbid state advances, the whole organ wastes, and the secreting structure shrinks, and at last inactive connective tissue alone marks the seat where most active and energetic changes once occurred. It is easy to see how such a substance as alcohol must tend to restrict the rapid multiplication of the cells if the process is too active, and how it would tend to promote the advance of disease in organs in which rapid change in the cells characterizes the normal state."*

Non-living pus-corpuscles are round and granular, about $\frac{1}{3000}$th of an inch in diameter. Dilute acetic acid renders them transparent, and brings into view one or more nuclei, bright and sharply defined. Neutral alkaline salts shrivel the pus-globules and caustic alkalies destroy them. Besides the globules, pus often contains free nuclei, red blood-corpuscles, epithelium, remains of connective tissue, crystals of the triple phosphates, infusoria, etc. The inspissation of pus sometimes results in a cheesy metamorphosis or *caseation*, which has been called tuberculization of pus (see the section on Fatty Degeneration, page 233).

In addition to pus-cells, there is in inflammation always more or less fluid exudation, or inflammatory effusion. This differs from the ordinary liquor sanguinis of the vessels in health by containing a larger proportion of albumen and fibrinogenous substance, as well as an excess of phosphates and carbonates. This exudation may be interstitial when between the tissues and parts, parenchymatous if seated within the tissues so as to enlarge them, or free if on free surfaces or natural cavities.

Serous exudations on free surfaces are called flux or

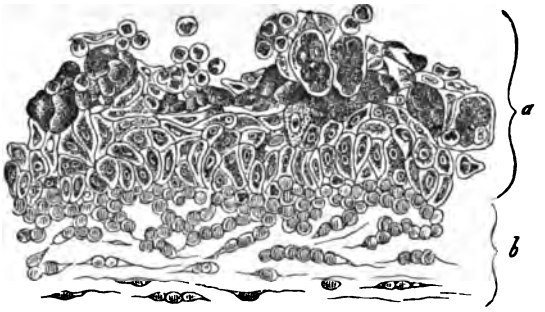
* The Physiological Anatomy and Physiology of Man, by Todd, Bowman, and Beale. Part I.

serous catarrh; into serous cavities inflammatory dropsy; into tissues, inflammatory œdema; under the epidermis, serous vesicles, etc. A serous exudation containing albumen is found in many inflammations of the kidneys (albuminuria), and of the intestine (dysentery), etc.

Mucous exudation, or mucous catarrh, occurs oftenest on mucous membranes, from the mingling of the epithelial cells with the increased flow from the vessels. The term "catarrh" came from the ancient idea that in a cold liquid flows from the ventricles of the brain through the ethmoid bone and nose.

In catarrhal inflammation of the mucous membrane there is first hyperæmia, then swelling of the membrane and lymph-follicles with an increased production of epithelial and mucous elements. The excessive growth of bioplasm in these elements, according to Beale, changes a simple mucous catarrh into a purulent one (Fig. 203).

FIG. 203.



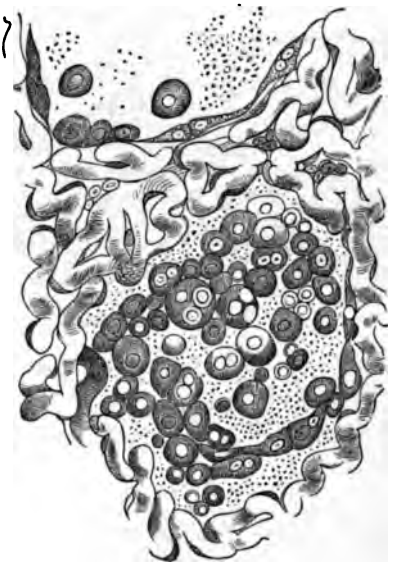
Catarrh (purulent) of conjunctiva. *a*. Epithelium. *b*. Connective tissue stratum of the mucosa.—After RINDFLEISCH.

In catarrhal (lobular or broncho) pneumonia there is a proliferation of the alveolar epithelium of lobules or groups of lobules connected with those bronchial tubes in which the catarrhal changes first began (Fig. 204).

If the patient recover, but the retained substances are incompletely removed, a thickening of the walls may result, with the formation of a caseous nodule.

Desquamative catarrh of the kidneys, Fig. 205, begins with a granular cloudiness and falling off of the epithe-

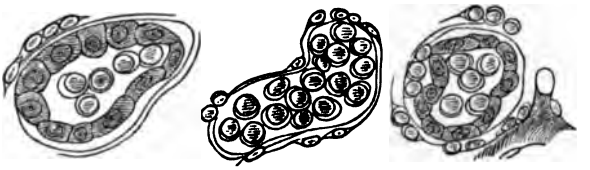
FIG. 204.



Catarrhal pneumonia. One and a half of an alveolus. The tortuous capillaries of the septa injected. Filling of the lumina with epithelial cells of the walls which multiply by division. 1-300.—After RINDFLEISCH.

lial lining of the uriniferous tubules, and an active proliferation of the cells.

FIG. 205.

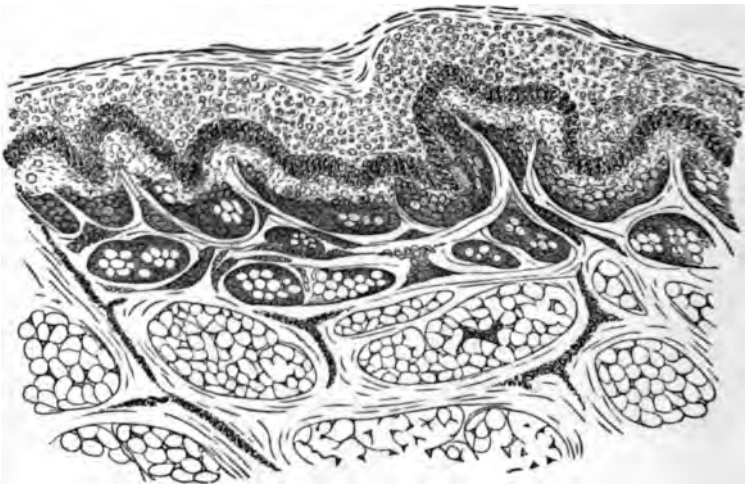


Transverse and oblique sections of catarrhal urinary tubuli. 1-500.—After RINDFLEISCH.

Rindfleisch calls vesicles and pustules produced by inflammation of the skin, an acute purulent catarrh of the skin, in which a primary serous catarrh (vesicle) became a purulent one (pustule). Eczema he terms a chronic

catarrh of the skin, having its origin in hyperæmia of the papillary layer (Fig. 206).

FIG. 206.



Vertical section through the skin after chronic eczema. *a*. Horny layer. *b*. Mucous layer of epidermis. *c*. Pigmented stratum of cylindrical cells. *d*. Papillary layer. *e*. Cutis pervaded by stripes of pigment.—After RINDFLEISCH.

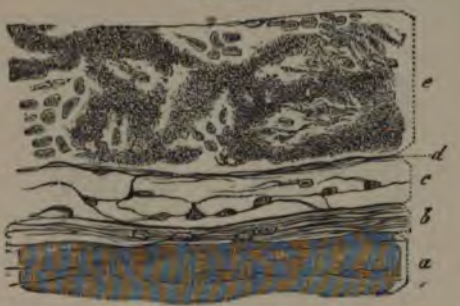
The stratum of Malpighi in the skin is analogous to the softer epithelium of mucous surfaces, but catarrhal processes in the skin are modified by the horny layer, which is first destroyed in the instances referred to, and then the multiplying epithelium cast off.

Fibrinous exudation consists of fluid from the hyperæmic vessels, which coagulates into fibres between whose meshes serum is confined. Pus-corpuscles are generally mixed with the exudation, constituting a fibrino-purulent exudation. These occur principally on the surface of serous membranes. The coagulated fibrin either glues the two surfaces of the membrane together, or forms a slightly adherent layer of membrane, in which the exuded cells develop a true connective tissue (Fig. 207).

The false membranes which occur in pleuritis or pericarditis, generally of rheumatic origin, are examples of

this result. The formation of pus in serous cavities (em physema, etc.) is well illustrated in Fig. 208.

FIG. 207.



Adhesive inflammation. Diaphragmatic pleura. *a*. Contiguous muscular structure of diaphragm. *b*. Subserosa. *c*. Serosa. *d*. Boundary of the serosa and the exudation. *e*. Exudation. 1-400.—After RINDFLEISCH.

Croupous exudation differs from fibrinous by having its origin in a peculiar metamorphosis of epithelium (Fig.

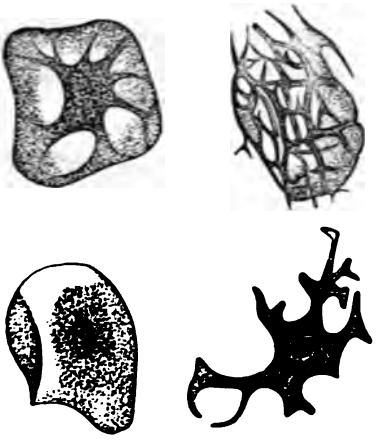
FIG. 208.

Purulent inflammation upon the serosa of the uterus. *a*. Serosa infiltrated with colorless blood-corpuscles. *b*. Surface secreting pus-corpuscles. *c*. Muscular structure. 1-500. —After RINDFLEISCH.

209). Wagner has shown that this change in the cells re-

sults in a delicate network, forming by its accumulation a flat grayish-white croupous membrane, or isolated deposits. According to this view, the network of croup-

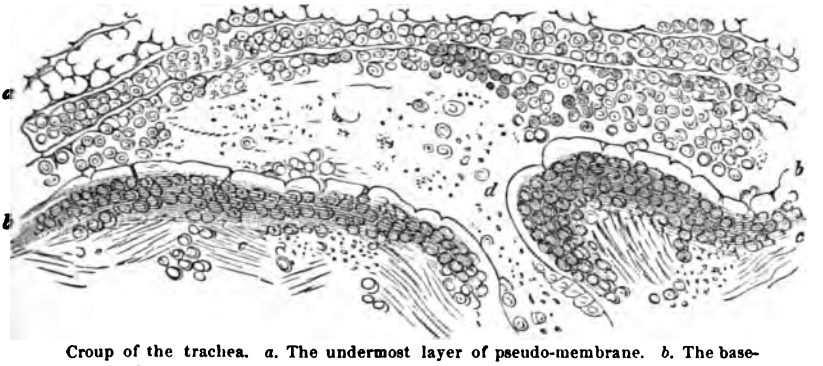
FIG. 209.



Fibrinous degeneration of pavement cells.—After E. WAGNER.

membrane occupies the place of epithelium. Other pathologists regard the network as analogous to the fibrinous network of inflamed serous membranes. Croup of the

FIG. 210.



Croup of the trachea. *a*. The undermost layer of pseudo-membrane. *b*. The basement membrane. *c*. The subepithelial germinal tissue. *d*. Excretory duct of a mucous gland, from which a clear mucus is evacuated and lifts off the pseudo-membrane. 1-1000. —After RINDFLEISCH.

larynx and trachea shows a combination of catarrh and pseudo-membranous exudation (Fig. 210).

Croupous pneumonia is generally an independent affection, while the catarrhal and interstitial forms of inflammation of the lungs usually result from preceding bronchial or pulmonary lesion. The first stage is that of engorgement, in which the capillaries dilate and coil so as greatly to diminish the air capacity of the alveoli. In the second stage, that of red hepatization (Fig. 211), the

FIG. 211.

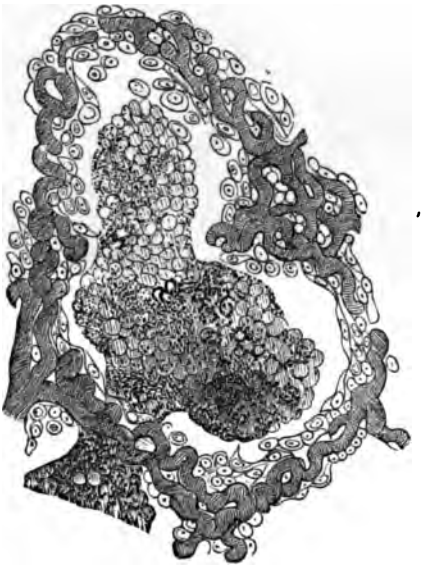
Recent croupous pneumonia. *a*. Alveolar septa with injected capillary vessels. *b*. The exudation. 1-300.—After RINDFLEISCH.

exuded contents of the capillaries of the air-cells, red and white corpuscles, and serum, are coagulated by the fibrin into a solid body. The third stage is that of yellow or gray hepatization, characterized by a greater proportion of white blood-cells and their progeny, mingled with the results of commencing fatty metamorphosis. Purulent infiltration, or resolution, is sometimes called the fourth stage of this disease. Here the fibrin melts down to a soft amorphous gelatin, and the young cells undergo fatty degeneration. Granular pigment also is mixed with the

softened matters, and appears in the expectoration (Fig. 212). Instead of resolution, in which the exudation is absorbed or cast out by the sputum, abscess, or gangrene, or chronic pneumonia may result, though rarely.

Diphtheritic exudation accompanies a greater hyperæmia of the mucous surface than croupous inflammation, and even of the submucous tissue, with a gangrenous separation of the infiltrated parts. Between the croupous and diphtheritic forms of exudation there is every possible transition.

FIG. 212.



Croupous pneumonia in a later stage of development. Melting down of the exudation. Catarrhal desquamation of the alveolar walls. 1-300.—After RINDFLEISCH.

Buhl regards diphtheritis as a general disease, which may be termed acute tissue necrosis, and is different from inflammatory, typhous, scarlatinous, or other forms of tissue necrosis.

The occurrence of fungi in diphtheritic exudation is almost constant. The *leptothrix buccalis* is the most com-

mon form. Similar forms occur in croup-membrane. Some suppose the fungus to be the primary cause of the disease, but the decaying morbid matter may merely form the habitat (see page 136).

RESOLUTION AND ORGANIZATION.

If the injury sustained by the tissue is not severe, or by medical skill the vascular activity is lessened, the in-

FIG. 213.

Section through the border of a healing surface of granulation. *a*. Section of pus. *b*. Tissue of granulation (germinal tissue) with capillary loops, whose walls consist of a longitudinal layer of cells, decreasing in thickness from within outwards. *c*. Beginning of the cicatricial formation in the deep layers (spindle-cell tissue). *d*. Cicatricial tissue. *e*. Complete epithelial covering. The central layer of cells consists of serrated cells. *f*. Young epithelial cells. *g*. Zone of differentiation. 1-300.—After RINDFLEISCH.

flammation may gradually subside or terminate in *resolution*. The congestion diminishes, the emigration ceases,

some of the cells undergo fatty degeneration and are absorbed, others are removed by the lymphatics, and the tissue returns to its normal condition.

If the inflammation does not end in resolution, after a diminution of intensity, there may be an *organization* of many of the new cells into a form of fibrillated tissue, as in the healing of wounds by "the first intention," and in many chronic inflammations of the liver, kidney, etc. In this *cicatricial tissue* the cells become *spindle-shaped* or elongated, with tapering ends. Sometimes, according to Green, a sort of adenoid tissue results, consisting of meshes of fibrillated material inclosing lymphoid cells.

After suppuration, organization takes place by *granulation* or the "*second intention.*" It takes place wherever the injured tissue presents a free surface to the air, as in an ulcer, or in a wound left open, etc. (Fig. 213). The young cells of the superficial layer develop into *granulation tissue*, which forms little papilliform nodules or *granulations.* The form of these granulations seems determined by the new capillary bloodvessels which grow rapidly in the new tissue. The deeper layers of the tissue gradually develop into fibrillated tissue, while the cells on the surface of the granulations and transuded liquid from the vessels are discharged as pus. The first formation of epithelium seems to consist of pus-corpuscles not thrown off, yet the influence of the neighboring normal epithelium is seen in the proliferating margins, as well as in the effect of skin-grafting, as it is called, on the surface of an ulcer. The new epithelium always remains thin and dry.

Pathological New Formations.

Increased nutrition leads not only to the enlargement of the component elements of a tissue, but also to the production of new elements by proliferation of bioplasm constituting new formations. These may be either inflammatory or non-inflammatory growths, occurring as

tumors, infiltrations, or numerical hypertrophies, the latter differing from simple hypertrophies, or increased size of the elements of tissues, by increase in the number of the elements, as of the muscular fibres in hypertrophied muscle, etc.

New formations are in all cases the direct product of pre-existing cellular elements, and their development resembles more or less the normal tissues. In other words, every pathological growth has its physiological prototype. If it is similar in structure and development to the tissue from which it originates, or in which it is situated, it is called *homologous;* when it differs, *heterologous.*

The elements from which new growths most frequently originate are those of the *common connective tissue* with its bloodvessels and lymphatics. This tissue must be distinguished from formed connective substances, as bone, tendon, cartilage, etc. Two kinds of cells are found in this tissue,—the connective tissue cells, which are stable, and the mobile cells, which are probably wandering leucocytes.

The first result of the abnormal activity of these cells is to produce a new tissue,—*embryonic* or *indifferent tissue,*—composed of small roundish cells, about $\frac{1}{2000}$th of an inch in diameter. This tissue afterwards develops into tissue of permanent growth, resembling the immature connective tissue of the embryo, and like that capable of becoming fibrous tissue, cartilage, bone, etc.

Next to common connective tissue, the *epithelia,* surface and glandular, are the elements from which new formations most frequently originate, and such growths generally resemble epithelium.

From the higher animal tissues, muscle and nerve, new growths are rare, if, indeed, they really occur at all. Beale says "the *fully formed* anatomical elements of a normal tissue could not give origin to a morbid growth."

The term *malignancy* is applied to a property possessed by many tumors of recurring after removal, of infecting

neighboring lymphatic glands, and of reproducing themselves in distant organs. It is not confined to carcinomas or cancers, since many sarcomas are just as malignant.

Pathological new formations are subject to retrogressive changes similar to those of physiological tissues. Deficient supply of blood is followed by fatty degeneration, with its varied terminations,—softening, caseation, and calcification. Pigmentary, colloid, and mucoid degeneration may also occur, or inflammation. In addition, one form of tissue may be transformed into another, especially of the same group, as of connective tissue elements. Thus cancers may form in cicatrices and tumors of various kinds, sarcomas in fibromas, etc.

Pathological new formations have been variously classified For convenience of the student we divide them as follows:

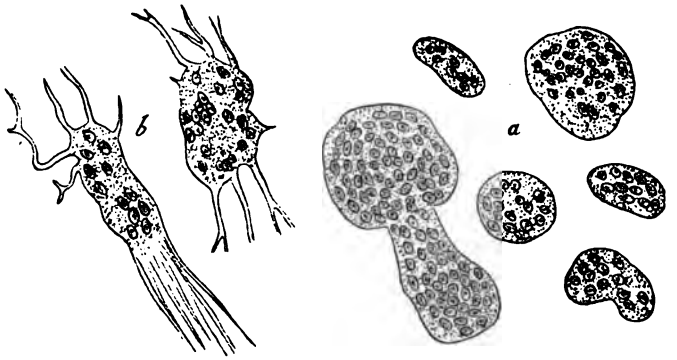
1. Pathological formation of cells
2. Pathological growth of higher animal tissues.
3. Pathological growths of connective tissue origin.
4. Pathological growths of epithelial origin.

I. NEW FORMATION OF PATHOLOGICAL CELLS.

We have already stated that proliferating cells, either tissue-cells or wandering leucocytes, produce abnormally, first, an embryonic or *indifferent tissue*. This seems identical with granulation tissue (page 262). From it various new growths proceed. The cells multiply as in normal tissues, by division, budding, or endogenous formation (page 125). Cell division affects the entire cell nucleus, nucleolus, and bioplasm. It is generally accomplished quickly, judging from experiments on the warm stage of the microscope (page 42). Budding is a variety of self-division, in which a small portion of bioplasm is protruded and separated so as to become an independent cell. In exogenous cell formation the nucleus, after previous division of the nucleolus, divides into two or more nuclei.

In the *giant cells*, so called, the nuclei number ten to fifty or more. Physiologically these occur in bone marrow, where they are regarded as transformed osteoblasts, and pathologically in granulation tissue and many tumors. In soft, yielding tissues their form is roundish, but in fibrous tissues the giant cells have peripheral processes (Fig. 214).

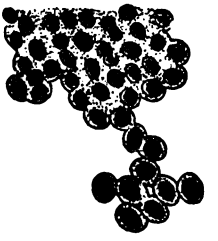
FIG. 214.



Giant cells. *a*. Roundish (Virchow). *b*. With processes. From a muscular tumor (Billroth).—After RINDFLEISCH.

Rindfleisch has pointed out a cell-formation in nucleus-bearing protoplasm, where apparently free nuclei are imbedded in homogeneous substance, but reagents show a differentiation of the protoplasm, so that to each nucleus belongs a small round cell. This is different from giant cells, and occurs in many sarcomata and cancers (Fig. 215).

FIG. 215.



Nucleated protoplasm. Fragment from a granulation.

Most cells are capable of increase. The movable and fixed cells of connective tissue, young bone, and cartilage cells; the youngest layers of epithelial cells, either of the surface or glandular; the nuclei of capillaries, of the sarcolemma,

etc., may any of them become points of departure for pathological new formations. The youngest formed, or embryonic cells, may be developed like the tissues of the embryo, may become connective tissue cells, bone-corpuscles, muscle-fibres, and, according to some, true epithelium, etc., or cancer-cells, sarcoma-cells, etc. The cells, however, which rise from various tissues usually give origin to definite new formations. Thus epithelial formations arise from epithelial tissue; connective tissue forms from connective tissue, etc.

II. PATHOLOGICAL GROWTHS OF HIGHER ANIMAL TISSUES.

1. *Muscular Tissue.*—*a.* Striated. Virchow, and after him Billroth and others, have shown that the elements of the more highly organized tissues, as the nervous and muscular, are rarely imitated pathologically.

Systematic writers term striated muscular tumors *rhabdomyoma*, or true myoma. The few instances referred to consist of a few fibres mixed with other tissues in cystic tumors of the ovary, testicle, etc.

b. Smooth muscular-fibre tumors, or *leiomyoma*,—fibroid, in the narrower sense,—occurring most frequently in the body of the uterus, either as submucous, intramural, or subperitoneal tumors, are so similar in their elements to the ordinary fibroma as not to be distinguished from it.

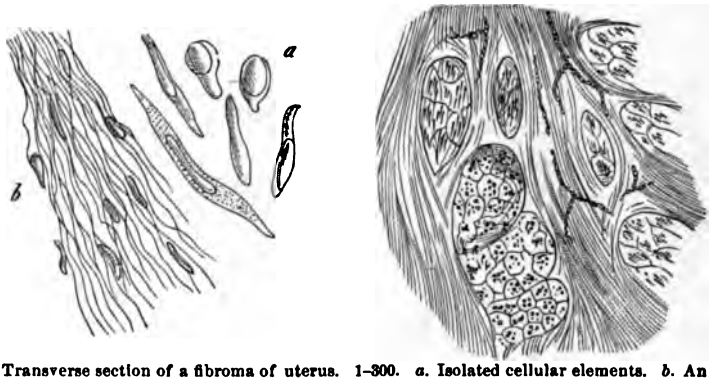
2. *Nervous Tissue.*—The term *neuroma* is applied to a fibrous tumor on a nerve. It is quite doubtful if the term is applicable. The cases recorded are small, roundish, hard tumors, occurring in the course of nerves, and nodules on nerves at the end of amputation stumps. They consist, however, of increased vascular connective tissue separating the nerve-fibres. Rindfleisch refers to a case which he deems a true neuroma. He says it is the first example of a genuine one, yet states that it may be a hypertrophied ganglion of the sympathetic.

III. PATHOLOGICAL GROWTHS OF CONNECTIVE TISSUE ORIGIN.

a. Common Connective Tissue Type.

1. *Fibroma* is a generally innocent growth, consisting essentially of fibrous tissue (Fig. 216). Fibromata are

FIG. 216.



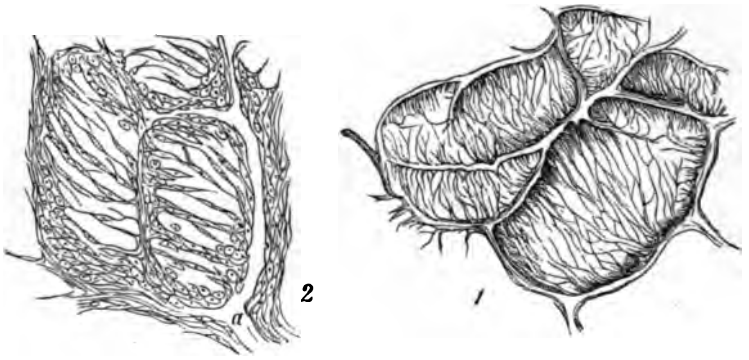
Transverse section of a fibroma of uterus. 1-300. *a*. Isolated cellular elements. *b*. An unravelled fasciculus of the fibroma. 1-500.—After RINDFLEISCH.

usually circumscribed, rarely diffused, and are composed of interlaced fibres and cells, like cicatricial tissue. The common fibroid is so dense that in cutting it creaks under the knife.

Fibromata occur on the trunk and extremities, proceeding from the skin (as *elephantiasis tuberosa*, etc.), from the subcutaneous and intermuscular connective tissue, from fascia, periosteum, bones, and bone-marrow; in the uterus and its vicinity, in subserous tissue, in submucous tissue, especially of the nose and throat; in nerves (as common neuroma and the subcutaneous painful tumor, or irritable tumor, as it is called); in glandular organs, as the mammæ and kidneys, etc. For the most part fibromata grow very slowly, but they are often combined with other forms.

2. *Areola fibroma*, or fibro-cellular tumor, consists of bundles of connective fibres with spaces containing serous or mucous fluid. It occurs in circumscribed or diffuse form. The circumscribed is found in the skin and subcutaneous tissue, especially of the scrotum, labia majora, around the vagina, in intermuscular connective tissue, periosteum, uterus, mammæ, etc. The diffuse occur oftenest in the skin as soft warts (*fibroma molluscum*, Fig. 217);

FIG. 217.



Fibroma molluscum. 1. Completed tissue, after Virchow. 2. Immature condition. Formation of clefts in the parenchymatous islands. 1–200. At *a*, the lumen of a vessel. —After RINDFLEISCH.

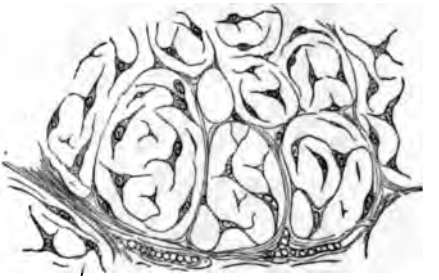
as elephantiasis of the scrotum, prepuce, labia, clitoris, of the extremities, nose, etc.; and as polypi in the submucous tissue of the pharynx, nose, uterus, etc.

b. Mucous Tissue Type.

1. *Myxoma*, or mucous tumor, occurs either pure or mixed with other tissues. It consists of a mucous basis-substance, with stellate or spindle-shaped anastomosing cells (Fig. 218), or in young myxomas, of small round cells, like mucous corpuscles. Myxoma form rapidly-growing, soft, knotty swellings, which may be mistaken for soft cancers. They may be classed with benign tumors, and do not return after thorough extirpation.

Myxomata occur in subcutaneous and intermuscular connective tissue, in fasciæ, medulla of bones, and in the interior and vicinity of glands. A myxoma of the placenta has been described as a vesicular mole, consisting in a hypertrophy of the mucous tissue of the tufts of the chorion, producing tumors, varying to the size of a cherry

FIG. 218.



Hyaline myxoma of the subcutaneous connective tissue in the neighborhood of the angle of the jaw. 1-300.—After RINDFLEISCH.

or larger; the whole mass may attain the size of a man's head. The fetal development in such a case varies according to the mass of the tumors.

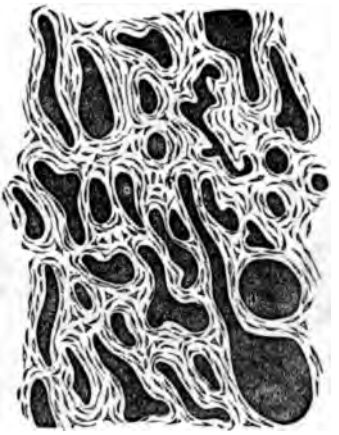
c. Vascular Connective Tissue Forms.

1. *Angioma*, or vascular tumor, is composed of blood-vessels held together by a small amount of connective tissue. The angiomata include the various forms of nævi, the erectile tumors, and aneurism by anastomosis.

(1.) Capillary angioma, nævus vasculosus, or teleangiectasia, is generally congenital. It occurs oftenest on the skin, in the papillary layer (mole, mother's mark, etc.), although it may occur in other structures. It may vary in size from that of a millet-seed to the occupancy of the entire face or extremity. It is flat, lobed, generally bluish or dark red, and consists of tortuous, varicose, or aneurismal capillary vessels and wavy connective tissue.

(2.) Cavernous or venous angioma, erectile tumor, or aneurism by anastomosis, is generally round, from the size of a bean to that of a walnut. It is similar in structure to the erectile cavernous tissue of the penis and clit-

FIG. 219.



The substance of the cavernous tumor in full development. 1-300. From a cavernous tumor of orbit.—After RINDFLEISCH.

oris, consisting of a network of fibres containing blood (Fig. 219). They are generally of a bluish color. Venous angiomata, consisting mainly of enlarged and tortuous veins, are often seen as internal or external hæmorrhoidal tumors.

(3.) Arterial angioma is sometimes met with, especially in the branches of the temporal and occipital arteries.

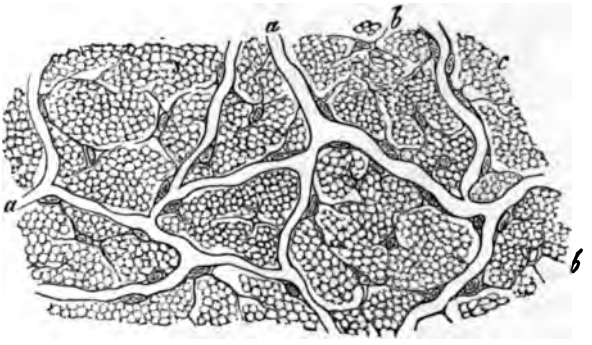
(4.) Lymphatic angioma is a similar dilatation of the lymphatic vessels, and has been principally noticed in connection with elephantiasis. Lymphangiomata of the kidneys and of the skin have also been described.

2. *Thrombosis* is a coagulation of the blood in the vessels during life, from impeded blood-flow or changes (as inequalities) in the walls of the vessels. It depends on separation of the fibrin from the blood. Dr. Schmidt has shown that the blood-corpuscles contain an albuminoid

substance (globulin, fibrino-plastic substance), which enters into union with a similar (fibrinogenous) substance, so as to form fibrin, the molecules of which have a great attraction for each other, producing a characteristic microscopic network of round filaments.

Thrombi must not be confounded with the coagula found in the dead. If the death-struggle has been long coagula are generally found in the right side of the heart, often extending into the pulmonary artery. A thrombus is lighter, firmer, and drier than a coagulum, and is often made up of concentric layers.

FIG. 220.



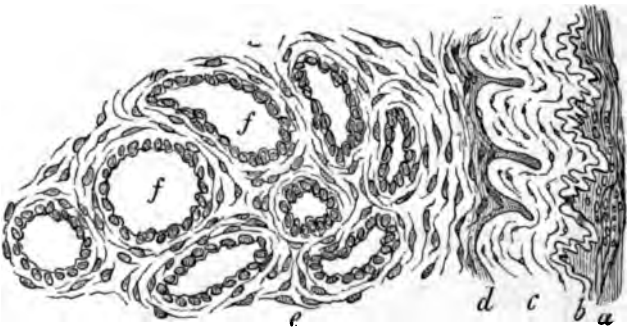
Cross-section through a thrombus by ligation of the crural artery, thirty-seven days old; hardened in alcohol, treated with dilute acetic acid, and then with a little ammonia. *a*. Capillaries. *b*. The cell-net of the colorless blood-corpuscles. In the basis-substance the contours of the red blood-corpuscles.—After RINDFLEISCH.

A thrombus once formed either organizes or softens.

If it organizes, the thrombus is gradually changed into connective tissue. This is by virtue of the vital power of the bioplasts, or white corpuscles. Thrombi have been produced in animals by ligation, and cinnabar injections into the blood have shown the wandering leucocytes, carrying cinnabar, at work in the blood-clot. They send out processes in various directions, which touch each other and form a more delicate net with nuclei at the points of intersection (Fig. 220).

Soon after vessels are formed in the thrombus, which give it an organlike connection with the body, as other pathological new formations. These vessels may widen and become cavernous, as in Fig. 221, and as the walls become thinner and finally disappear the thrombus ceases to exist.

FIG. 221.



From the cross-section of an arterial thrombus of three months. *a.* Media, only the innermost layers. *b.* Boundary lamella of the media and intima. *c.* Intima. *d.* Boundary of intima towards the thrombus. *e.* Thrombus. *f.* Lumina of vessels. Distinct epithelium. 1-300.—After RINDFLEISCH.

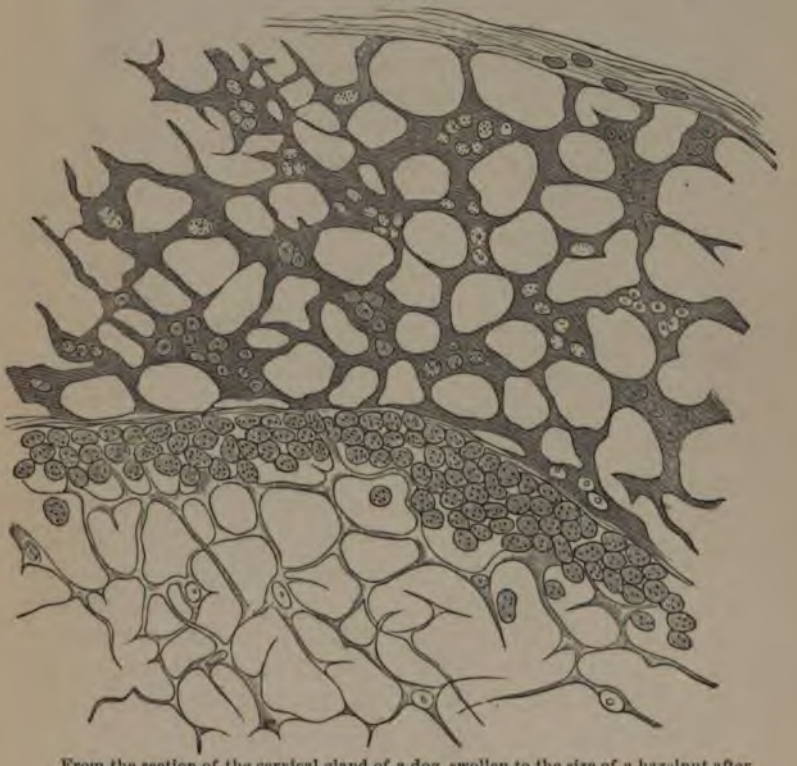
The softening of the thrombi is a dangerous process. Fragments may be carried from the radicles of the vena cava through the right heart to the lungs; from the radicles of the pulmonary veins through the left heart to the various organs of the body; or from the radicles of the portal vein to the liver. Such particles may occlude the vessel in which they are found, producing *embolism*, the results of which may depend on the mechanical obstruction to the circulation (anæmia and softening), or on the irritating or infective properties of the emboli (pyæmia).

a. Adenoid or Reticular Connective Type.

1. *Lymphoma.*—This is a new formation of lymphatic or adenoid tissue, and is generally found as small tumors or infiltrations, consisting of rounded bright nuclei, and

small cells, like leucocytes, lying in semifluid or fibrous intermediate substance. Lymphomata occur in typhoid fever in the small intestine, in the mesenteric glands, and liver. Lymphatic tissue always consists of a reticulum of branched cells, within the meshes of which the lymphatic corpuscles are contained. It is closely allied to embryonic tissue, and is easily influenced by any irritation whatever to excessive development. Inflammatory states

FIG. 222.



From the section of the cervical gland of a dog, swollen to the size of a hazel-nut after artificially produced inflammation of the lips. 1–500. After Billroth. Connective tissue septum. Sinus terminalis. Border of lymph alveoli.—After RINDFLEISCH.

of the organs from which the glands receive their lymph produce suppurative, cheesy, and indurated lymphadenitis (Fig. 222).

The adenomata are generally innocent. The glands which are most prone to increased growth are the cervical, submaxillary, axillary, inguinal, and abdominal glands. Sometimes several glands unite so as to form large lobulated tumors. The enlargement of the spleen in ague is probably of this nature. Leucocythæmic new formations occur generally in the spleen, the lymph glands, and perhaps the medulla of bones.

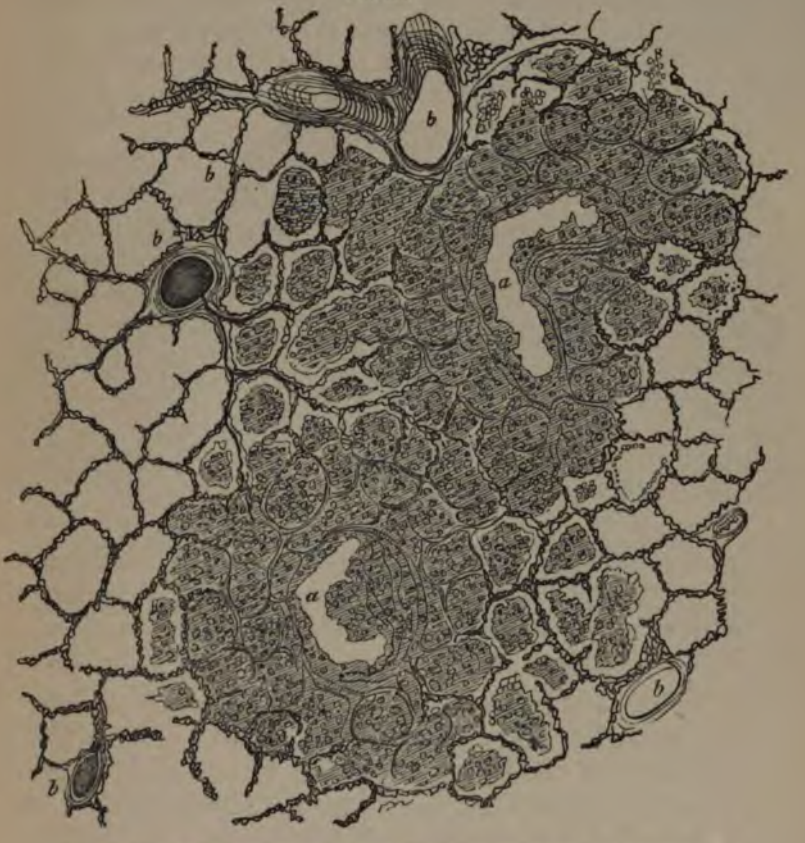
2. *Tubercle* is an infiltrated or nodular new formation, generally multiple, or miliary, non-vascular, round or irregular, made up of large and small nuclei, indifferent cells, and giant cells, imbedded in reticular tissue. After long induration it passes into cheesy atrophy, or into softening, and produces not only local affections but also constitutional disease (tuberculosis and scrofulosis). It was formerly considered to be a specific non-inflammatory growth originating spontaneously, and characterized by a regular succession of changes, first gray and translucent, then opaque, and finally caseous. Modern histologists regard it as due to infection from the absorption of the products of inflammatory processes. Caseation after fatty degeneration (page 233) may become a focus of self-infection, so that caseation and tubercle may occur side by side. The nodules of tubercle are sometimes microscopic in size, as in the liver or meninges of the brain. When they reach the size of a millet-seed they are termed *miliary tubercles* (gray tubercle, semi-translucent granulation). If as large as a pea, cherry, egg, etc., they are *large tubercles* or conglomerate nodules. Still later they are known as *yellow tubercles*, from their being yellow and cheesy in the centre.

In Fig. 223 is a view of two broncho-pneumonic depots, the size of a millet-seed, illustrating a pseudo-tuberculous condition.

See also page 254, where catarrhal pneumonia is stated to precede a caseous nodule.

In contrast with this Fig. 224 shows the deposit of miliary tubercle as it occurs in tubercular meningitis.

FIG. 223.



Two smallest broncho-pneumonic depots. Tubercle granulation of Laennec. *a*, *a*. The lumina of two adjacent small bronchi, the caseous secretion partially fallen out; the walls infiltrated with cells and directly going over into catarrhal infiltration of the surrounding parenchyma. By the course of the elastic fibres we may recognize everywhere how large the number of infiltrated alveoli is. *b*, *b*, *b*. Bloodvessels. 1–100 mm.—After RINDFLEISCH.

The inflammatory growth originates in the perivascular lymphatic sheaths which inclose the small arteries of the

pia mater. The cells of the sheath multiply, and numerous gray nodules are produced around the vessel.

Microscopically, Wagner describes fresh miliary tubercle as consisting of one or more (from four to six generally) rounded follicles or nodules, each composed of a

FIG. 224.

Vertical section through the pia mater and the contiguous portion of the cortex of brain in tubercular meningitis. *a, a.* A larger vessel of the pia mater whose entire sheath is inflammatorily infiltrated. *b, b.* Lymph-spaces of the pia mater with commencing tubercular proliferation of the endothelia. *c.* Miliary tubercle of the pia mater. *d.* Outermost layer of cortex of brain infiltrated with round cells. *e.* Normal brain-substance. *f, f.* Proper cerebral vessels in a state of tuberculous degeneration.—After RINDFLEISCH.

reticulum and cellular elements. The latter are free nuclei, cells like leucocytes with one or two nuclei, and in the centre of the follicle one or more polynuclear giant cells. The latter are granular and branching, with 20 to 100 rounded and comparatively large nuclei. In addition there are cells of intermediate size, epithelial-like, rounded, and finely granular. Tubercle always occupies the place of normal tissue, which is either wasted or pushed aside by it.

There may be atrophy or necrosis of the elements of tubercle, after which cornification may transform it into a hard horny mass. Resorption rarely occurs, but calci-

fication will sometimes produce stony masses, which are occasionally laminated. Most often softening or liquefaction occurs simultaneously with cheesy metamorphosis, leading on mucous surfaces to tuberculous ulcers, and in the parenchyma of organs to tuberculous cavities or abscesses.

e. Neuroglia or Nerve-cement Type.

1. *Glioma* is an increase of the elements of the finely granular and reticular tissue or connective substance of nerve. The nervous elements do not participate in it. Glioma formerly went under the name of sarcoma, being considered a variety of round-celled sarcoma, but the locality and origin of these tumors entitle them to separate consideration. They are generally cerebral, and produce symptoms of pressure or irritation. In the retina they may begin as a white nodule, which grows until it may project from the orbit as a large fungous tumor. According to the relative proportion of cells, intermediate substance, and vessels, they are divided into soft, hard, and teleangiectatic gliomas. Gliomas are of very slow growth, and may become metamorphosed by hæmorrhages, fatty degeneration, and cystoid softening. Healing may be possible through fatty metamorphosis.

f. Type of Fatty Tissue.

1. *Lipoma.*—A general formation of new adipose tissue, hereditary or acquired, is termed *obesity.* A local and circumscribed formation is a lipoma or fatty tumor. The connective tissue unites the fat-cells in masses and lobules, and forms a distinct capsule. Lipomata are sometimes pedunculated. Their growth is slow, and although they may attain considerable size they are perfectly benign tumors.

Xanthoma, or xanthelasma, are small yellowish fatty tumors of the skin, generally of the face or eyelids. They

are sometimes nodular, like millet-seeds or grains of wheat, isolated or in groups.

g. Cartilage Type.

1. *Enchondroma or Cartilaginous Tumor.*—Like cartilage, this consists of cells and intercellular substance, the latter being hyaline, fibrous, or mucoid. The cells are often spindle-shaped or stellate. Enchondromata rarely develop from cartilage, but from bone and connective tissue. A large majority have their seat upon bones, especially at the diaphyses of the long bones. They are usually single, except on the fingers and toes, where they are often multiple. An ossifying enchondroma is called *osteochondroma*. The enchondromata, especially those which originate from cartilage, may be regarded as benign, yet encapsulated forms originating from bone or connective tissue are often injurious from the rapidity of their growth. The softer forms, such as occur in the medulla of bone, are sometimes malignant.

h. Type of Bone Formation.

1. *Osteoma.*—An osseous or bony tumor. An outgrowth from pre-existing bone is an *exostosis* or *osteophyte*. Such outgrowths proceed from the periosteum, the articular cartilage, or the medulla. In the latter case they might be properly termed *enostoses*. These are homologous tumors, since they are similar in structure to the tissue in which they are found. The osteomata, however, may be heterologous, as growing from connective tissue or cartilage apart from bone. They are of two kinds: 1. The ivory or hard tumors, in which there is a marked absence of cancellated bony tissue. 2. The soft or cancellous, which are spongy. The medullary cavities are sometimes quite large.

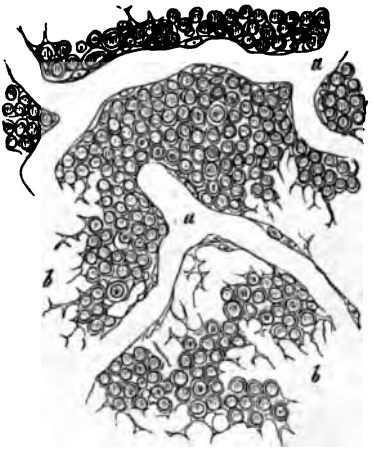
Osteomata are innocent tumors. Those osseous growths

which exhibit malignancy are ossified sarcomata or ossified cancers.

i. Other Forms Analogous to Connective Tissue Type.

1. *Sarcoma.*—Fibro-plastic or fibro-cellular tumor. It belongs to the group of connective substance tumors by some of its affinities, but is to be distinguished by the greater development of its cellular elements. All the sarcomata consist of embryonic connective tissue, and the

FIG. 225.



Round-celled sarcoma. *a*. Vascular lumina. *b*. Parenchyma partly brushed out, so that the hardened basis-substance appears as an elegant network. 1-300.—After RINDFLEISCH.

several varieties are dependent on the size and shape of the cells and the nature of the intermediate substance. They include what are termed *recurrent*, *fibroid*, and *myeloid* tumors.

(1.) *Round-celled sarcoma* is allied to granulation and embryonic tissues (page 262).

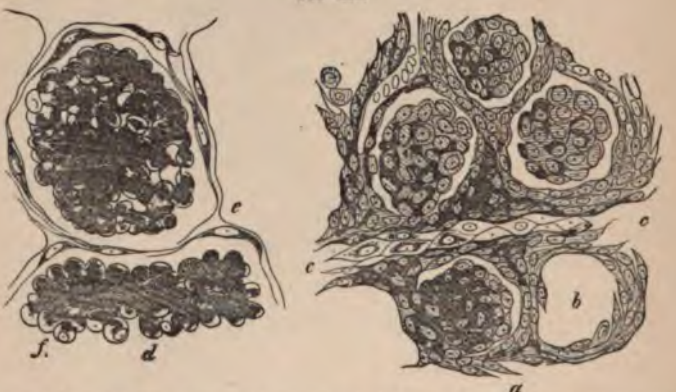
a. The *granulation-like* round-celled sarcoma, of soft consistence, containing embryonic cells in a homogeneous or finely granular intercellular substance.

b. The *lymphatic glandlike* round-celled sarcoma exhibits round cells in a delicate network of fibres among wide thin-walled capillaries (Fig. 225).

There are several varieties of these lymphadenoid sarcomas, as the *lipomatous sarcoma*, in which the cells by infiltration are transformed into fat; the *mucoid sarcoma*, from mucoid metamorphosis; and the *large-celled round-celled sarcoma*, which seems almost epithelial in its character of cells, with a large-meshed network. This tumor is soft and brainlike, and may be easily confounded with the following:

c. The Alveolar Round-celled Sarcoma.—This has a great resemblance to cancer, and has been called sarcoma carcinomatodes. It consists of groups of cells not connected

FIG 226.



Alveolar round-celled sarcoma, pigmented. *b.* Alveolus from which the ball of round cells has fallen out. *c.* Vessel with pigmented endothelia. *d.* Pigmented round cells. *e.* Spindle cells forming a stroma.—After RINDFLEISCH.

by basis-substance, but held in alveoli or clefts of connective tissue. The cells resemble epithelium. An exceedingly malignant variety has been called *pigmentary cancer* (Fig. 226).

(2.) *Spindle-celled sarcomata* are divided into—*a*, *small-celled spindle-celled sarcomata* (Fig. 227), which resembles

the spindle-celled tissue of recent cicatrices; *b*, *large-celled spindle-celled sarcomata*, in which the cells attain an excessive development (Fig. 228); and *c*, the *pigmentary sarcomata*.

FIG. 227.

Spindle-celled scarcoma. Gaping vascular lumina. The cell lines are divided partly longitudinally, partly transversely. 1-300.—After RINDFLEISCH.

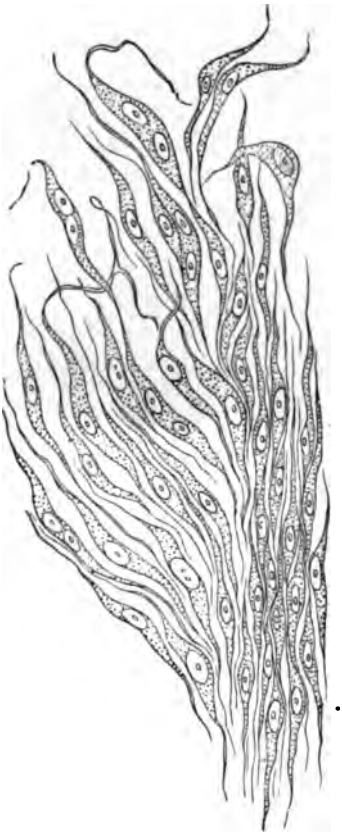
(3.) *The giant-celled sarcomata*, called also myelo-plastic and myeloid sarcomas, contain large cells, with numerous nuclei and nucleoli in a finely granular substance (Fig. 229). These occur usually on bones.

Sarcomata are rarely found in internal organs. They usually arise from common connective tissue, and the influence of locality on them is obvious. Thus on the surface of bone we have osteoid sarcomata, pigmented sarcomas in the skin and choroid, soft and gelatinous sarcomata in the glands, etc. Complete cure sometimes follows extirpation, but at other times there is a recurrence in the cicatrix, giving rise to the term recurring fibroid. Like other tumors they may inflame or become atrophied, or fatty metamorphosis, calcification, etc., may occur in them.

2. *Syphiloma.*—Gumma-syphiliticum. Gummy tumor.

This is a new formation, depending on constitutional syphilis. Its essential elements resemble leucocytes imbedded in connective tissue which is poor in vessels. It exhibits many transitional forms to granulation tissue

FIG. 228.



Large-celled spindle-celled sarcoma.—After VIRCHOW.

and sarcomata. Atrophy or fatty metamorphosis of the cells may produce cavities or caverns and cicatricial marks on the surface, leading to deformities (Fig. 230).

3. *Lupus* consists of nuclei and cells, forming a diffuse or nodular infiltration of the corium of the skin, generally

FIG. 229.

Giant cells. *a*. Roundish (Virchow). *b*. With processes. From a muscular tumor (Billroth).—After RINDFLEISCH.

of the face, and sometimes of the bordering mucous mem-

FIG. 230.

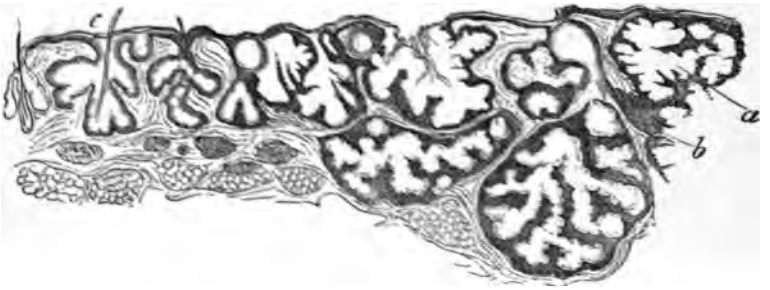
Syphilis of liver. *a*. Left. *b*. Right lobe of liver. *c c*. Connective tissue sheath, which penetrates the organ in the direction from the porta to the lig. suspensorium, and contains gummata. 2-1.—After RINDFLEISCH.

brane. Rindfleisch considers it to begin with a luxuriant

cell proliferation in the interstitial and encapsuling connective tissue of the sebaceous and sweat glands (Fig. 231). If the skin appears normal, or there is a moderate scaling till the lupus elements are resorbed, and there is left behind a smooth or radiating cicatrix, it is called *lupus non exedens*. *Lupus exedens*, or *rodens*, is ulcerative.

4. *Lepra—Elephantiasis Græcorum*.—Leprosy formerly prevailed all over Europe, but is now confined in that division of the globe to Iceland, Norway, the northern

FIG. 231.



Lupus. Section showing the transition of the healthy skin into the highest degree of infiltration. *a*. Acinous alveoli. *b*. Germinal tissue of the lupus nodule. *c*. Metaplastic hair-follicle and sebaceous gland. 1-10.—After RINDFLEISCH.

provinces of Russia, and the borders of the Caspian and Mediterranean seas. It still remains in Asia Minor, Arabia, Egypt, India, China, and the Hawaiian Islands. It is rarely cured, and generally destroys life by some secondary affection, as anæmia, diarrhœa, pneumonia, meningitis, etc.

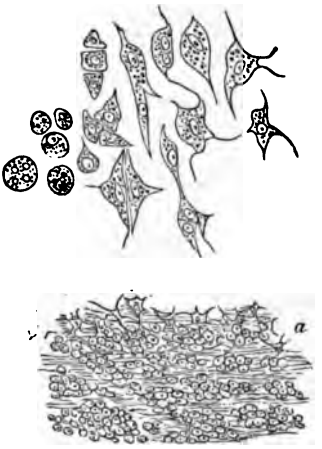
L. tuberculosa, the common form, is characterized by a nodular formation in the skin and other organs. The microscope shows these to consist usually of round granular cells with granular albuminous intercellular substance (Fig. 232).

These nodules soften and form ulcers, yielding a thin sanious pus, which dries to a brownish crust.

In *L. anæsthetica* the nodules are absent, but there is

found on the spinal cord a thick yellow dense mass of a diffuse leprous new formation, producing first paralysis of sensation, and later of motion, with mummification and necrosis of the skin, gangrene of fingers and toes, etc. Sometimes both forms are combined in the same patient.

FIG 232.



a. Lepra tissue, after Virchow. Cells in division.—After RINDFLEISCH.

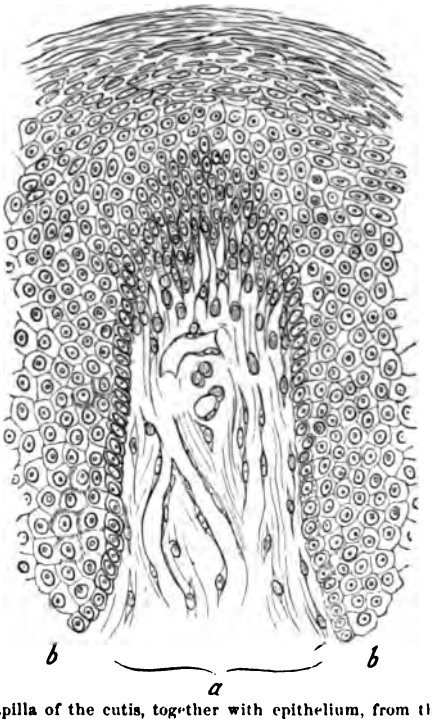
IV. PATHOLOGICAL GROWTHS OF EPITHELIAL ORIGIN.

1. *Papilloma — Papillary or Villous Tumor.*—Papillomata are analogous to the vascular papillæ of the skin, villi of the intestine, etc., and are composed of a vascular connective tissue body or basis, covered with epithelium (Fig. 233).

They form therefore a connecting link between the epithelial and connective tissue types. The quantity of epithelial growth varies in different papillomata In the skin it is abundant, and the superficial layers are hard and stratified, but in mucous membranes it is thinner and softer, while in serous membranes it is only a single layer. Papillomata of the skin include warts and horny growths;

those of mucous membranes are often classed as mucous polypi. The latter occur on the tongue, in the larynx and nose, on the cervix uteri, etc. In the bladder and intestine they are very vascular and produce profuse

FIG. 233.



A hyperplastic papilla of the cutis, together with epithelium, from the environs of a cancroid of the lip.—After RINDFLEISCH.

hæmorrhage. Here they are often mistaken for villous epithelioma, since the symptoms are similar and scarcely distinguishable till after death. In the papillomata the epithelium is homologous, being situated only on the surface, and in no case growing within the connective tissue basis. In the epitheliomata it is heterologous and is met

with in the subjacent connective tissue. Yet a simple papilloma may develop into an epithelioma.

2. *Adenoma, or Glandular Tumor.*—This forms sharply defined, and generally encapsuled, knots of new-formed glandular tissue. Its structure resembles that of racemose or tubular glands, and consists of numerous saccules or tubes lined with squamous or cylindrical epithelial cells. These are grouped together, being separated by a small amount of vascular connective tissue.

As sarcomata, myxomata, etc., occurring in glandular organs, have more or less glandular tissue, it is often difficult to see which predominates, hence the terms *adeno-sarcoma*, *adeno-myxoma*, etc.

Adenomata of the skin vary in size to that of an egg, and originate from sweat or sebaceous glands. Rindfleisch considers lupus to be of this nature (see Lupus).

Adenomata of mucous membranes form *mucous polypi*, which are usually broad, rarely pedunculated, and grow from the size of a bean to that of a hen's egg. The surface of such tumors is like that of the mucous membrane, but internally it may be fibrous and vascular, or even cystic. They occur on all mucous membranes, but oftenest in the nasal cavity, rectum, and uterus. The consequences of these adenomata depend on their size and anatomical relations. Thus they may form obstructions and give rise to catarrh and hæmorrhage.

Adenomata of glands occur more especially in the mamma, parotid, prostate, liver, and thyroid. Adenoma of the thyroid is known as *goitre*. Adenoma of the mamma (Fig. 234) is called by Billroth a "true epithelial glandular carcinoma." The only difference between it and a genuine epithelioma or carcinoma appears to be that the proliferatien of the epithelium is confined to the dilated glandular cavities, instead of infiltrating the separating walls, as in cancer.

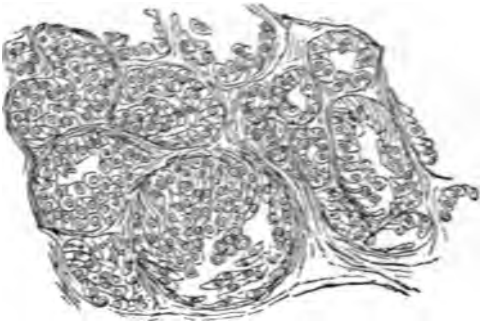
Some ovarian cysts—myxoid or colloid cystomata—

(page 239) belong to the adenomata. They proceed from the rounded or elongated saccular epithelial masses which form the processes of the Graafian follicles.

Adenomata are usually benign formations, but have a tendency to pass into cancer.

3. *Carcinoma, or Cancer.*—The term cancer is applied to an epithelial new formation which may occur as a tumor or infiltration in any tissue or organ, which is quite

FIG. 234.



Adenoma mammæ. Genuine epithelial carcinoma (Billroth). 1-300.—After RINDFLEISCH.

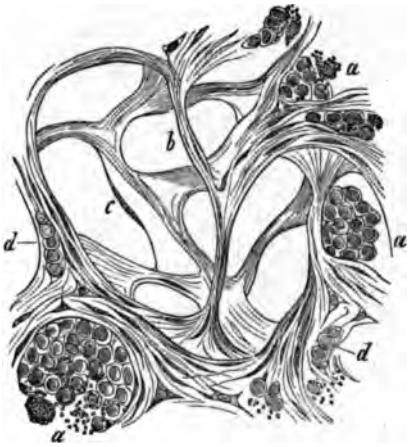
malignant, but which is generally (not always) chronic in its course. Its cells are not peculiar, being similar to other physiological cells, but by their rapid multiplication and metamorphoses are followed by destruction of the affected parts of the organ, and finally of the organ itself. It usually returns after extirpation, or it may secondarily affect internal organs. We have seen, page 264, that malignancy is by no means an exclusive property of cancers, since other new formations may be equally malignant.

Cancer occurs in various forms, as *scirrhus*, *encephaloid*, and *colloid*. Some consider epithelioma also to be a form of cancer, but as it is not as malignant as other forms, and is characterized by its local growth, it may be best considered separately as cancroid rather than true cancer.

Histologically, the forms of cancer resemble each other in consisting of cells of an epithelial type, without intercellular substance, grouped in irregular nests within the alveoli of a fibroid stroma (Fig. 235).

The differences between various forms of carcinoma are chiefly dependent on the greater or less proportion of cells and fibrous stroma. The deposit of pigment, forming *melanotic cancer*, as it is termed, may also be a cause

FIG. 235.



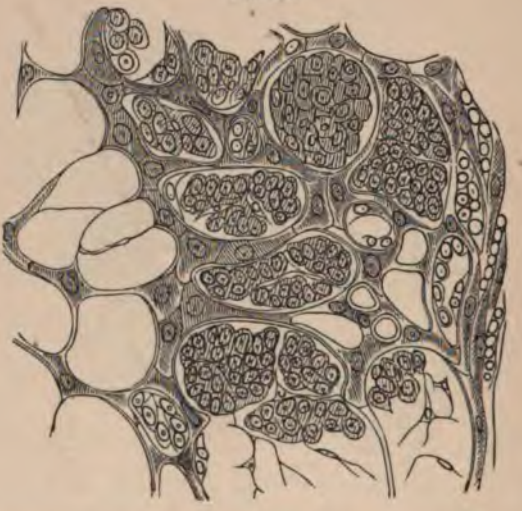
Brushed-out stroma of soft glandular cancer. *a*. Section of cylinder of cancer-cells. *b*. Trabeculæ of the stroma. *c*. A single spindle-cell, which extends from one trabecula to another, and by the separation of basis-substance along its protoplasm gives the impulse to the formation of a new trabecula of the stroma. *d*. Round-celled infiltrate in the interior of the trabeculæ of the stroma. 1-300.—After RINDFLEISCH.

of variety; so also ossification of the stroma (*osteoid cancer*) and the multiplication and enlargement of the vessels, as in *fungus hæmatodes;* but for the purposes of study the three forms referred to are sufficiently characteristic.

A difference of opinion exists as to the origin of the epithelial-like cells in cancers. Billroth and others regard them as starting only from pre-existing epithelium, while Virchow, Rindfleisch, etc., consider that they may be also

derived from connective tissue. It is not at all improbable that any kind of bioplasts, as Beale maintains, may form such growths by rapid proliferation, although the weight of evidence justifies us in regarding epithelial structure as the most frequent origin. The two following figures from Rindfleisch shows two different forms of origin in carcinoma of the liver. Fig. 236 shows the nor-

FIG. 236.



Carcinoma hepatis. The production and structure of pigmented radiary cancer. The liver-cell net forms the first foundation of the stroma, while the cancer-cells are deposited in the lumen of the vessels. 1-400.—After RINDFLEISCH.

mal liver-cell as furnishing the first foundation of the stroma, while the cancer-cells are found in the vessels. The liver-cells are generally pigmented. The spindle-formed and stellate cells which are also seen in the more delicate trabeculæ of the stroma have nothing to do with the liver-cells. In common cancer of the liver the vessels form the origin of the stroma, while the cancer-cells come from the liver-cells (Fig. 237).

(1.) *Scirrhus.*—Hard, fibrous, or chronic cancer. This is characterized by the large amount of its stroma and its chronic growth. At the external surface of a scirrhus tumor the microscope shows cells of indifferent, or granulation, tissue infiltrated among the muscular or adipose tissue of the part affected. At a little greater distance within these cells have developed into nests of cancer-

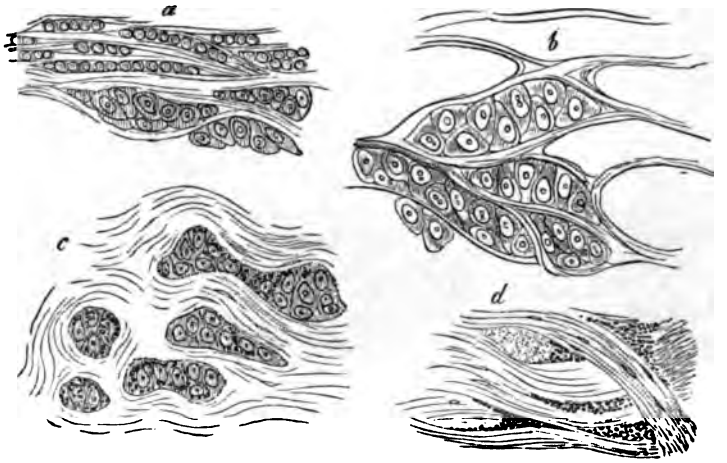
FIG. 237.

Carcinoma hepatis. The production and structure of diffuse medullary cancer. The vascular network forms the first foundation of the stroma, while the liver-cells are converted into cancer-cells. *a*. Normal liver-cells. *c*. Parenchymatous inflammation. *b*. Nests of cancer-cells. *v*. Vena centralis. 1–400.—After RINDFLEISCH.

cells, while the interstitial inflammation has produced an abundant stroma from the growth of pre-existent connective tissue, the trabeculæ of which are pressed asunder by the advancing cell-formation. Nearer the centre we find the cancer-cells in a state of retrogressive metamorphosis, producing a diminution in the size of the alveoli, and leading to a puckering of the external surface of the tumor. Fig. 238 exhibits each of these stages.

Scirrhus is generally met with in the mammæ and in the alimentary canal. It is quite hard previous to passing into the ulcerative stage, and on section the tumor exhibits a grayish-white glistening surface with occasionally fibrous interlacing bands. Scraping the juice from such a tumor may suffice for a cursory microscopic examination of its cells.

FIG. 283.



Carcinoma simplex mammæ. *a*. Development of nests of cancer-cells. *b*. Fully formed carcinoma tissue. *c*. Commencing cicatrization; at the same time a representation of the relations of stroma and cells in scirrhus. *d*. Cancer cicatrix. 1-300.—After RINDFLEISCH.

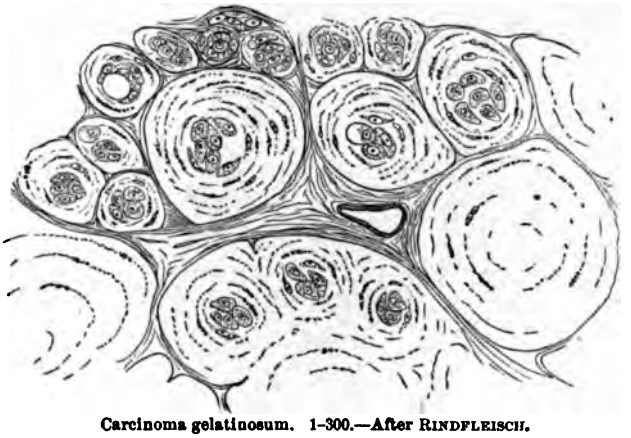
(2.) *Encephaloid.*—Medullary or acute cancer differs from scirrhus in the rapidity of its growth, and consequent softness of its structure. It is generally so soft as to be brainlike, hence the term encephaloid. There are, however, all intermediate stages of hardness in cancers between the extremes of scirrhus and encephaloid. In the latter epithelial growth is very rapid, and the proportion of stroma small, while the abundance and softness of the bloodvessels produces frequent hæmorrhages.

Encephaloid occurs generally in the internal organs as a secondary growth after extirpation of a cancerous

tumor, although it may occur primarily also, as in the articular ends of bones, in the eye, in the testicles, etc.

(3.) *Colloid.*—Alveolar or gelatinous cancer. This form depends on the metamorphosis of one of the preceding forms, the cells of which undergo a mucoid or colloid change. It is exceedingly malignant, and may occur in the stomach, large intestine, liver, ovary, or mammary gland (Fig. 239).

FIG. 239.



Carcinoma gelatinosum. 1-300.—After RINDFLEISCH.

4. *Epithelioma.*—Cancroid, or epithelial cancer, always grows in connection with a cutaneous or mucous surface, and its epithelial elements resemble the squamous variety of epithelium so as scarcely to be distinguished from the normal cell. They sometimes have more than one nucleus, and are often flattened and distorted by mutual pressure. They are not so ready to undergo fatty degeneration as the cells of other varieties of carcinoma. As the cells multiply they have a marked tendency to be arranged concentrically in groups, forming globular masses —" epithelial pearls," " bird's-nest bodies," etc. (Fig. 240).

There is little doubt as to the epithelial origin of the

cells in epithelioma. It may be said of this structure, as well perhaps of all varieties of carcinoma, that it is composed of epithelium run mad,—epithelium become heterologous,—extending beyond its normal limits into subjacent tissues. Epithelioma is first seen as a small foul ulcer with indurated edges, or as an induration or nodule which

FIG. 240.

Section of a cylinder of epithelial cells, under a magnifying power of 500. *a*. The cylinder itself, with the characteristic stratification of its cells, a younger and an older pearly globule. *b*. The stroma, very rich in cells at *c*, and contributing directly to the enlargement by apposition of the cylinder.—After RINDFLEISCH.

subsequently ulcerates. The surface of the ulcer is often villous, and the cut surface yields on pressure a small quantity of turbid fluid, or a thick curdy material like the sebaceous matter of the glands of the skin. This is composed of epithelium. Epithelioma often occurs on the lower lip at the junction of skin and mucous membrane. It may also grow on the tongue, scrotum, etc., and by its development may involve any tissue whatever.

Wagner describes three varieties of epithelioma: the *papillary*, or warty pavement-cell cancer, whose surface

is similar to warts or pointed condylomata; *cicatricial*, occurring usually in the skin of the face of old people as a superficial slowly growing cancer presenting a cicatricial contraction of the stroma from gradual retrogression and reabsorption of the cells; and the *mucous* cancroid, or cylindroma, characterized by cylindrical or arborescent masses of mucous substance.

The term *cylindrical epithelioma* has been given to those forms which appear on mucous membranes with columnar or cylindric epithelium. The tumors present the same epithelial elements as the tissues whence they grow. The walls of the alveoli show columnar epithelium, so that the distinction between such tumors and simple adenomata is very difficult. A variety of this form occurs as a villous growth on mucous membranes, as the bladder, uterus (cauliflower excrescence), and stomach.

CHAPTER XIV.

THE MICROSCOPE IN DIAGNOSIS.

In diagnosis the microscopical observer is necessarily confined to an examination of the various fluids and discharges of the body. Dr. Pritchard's microscope for examining the circulation of blood in the frænum of the human tongue, described by Dr. Beale, is an ingenious attempt to investigate the actual condition of the living subject, and indicates a direction which may hereafter be profitably pursued, but as yet is too refined for the purposes of the practical student.

I. THE BLOOD IN DISEASE.

The normal structure of blood has been sufficiently described at page 186. It remains now to point out briefly

the methods of examination and considerations useful in diagnosis.

The presence of too large a proportion of white corpuscles (leucocytes) in the blood constitutes what is known as leucæmia, and is usually associated with morbid changes in the spleen and lymphatic glands. But the relative numbers of white and red corpuscles vary in different persons, at different times, and in different morbid states, so that great care is needed in forming an opinion. Thus in anæmic and cancerous patients the proportion of white corpuscles is increased.

Prick the skin of the finger with a needle after moderate compression, and place the drop of blood thus obtained on a perfectly clear slide, and cover with thin glass in the usual way. No more blood should be taken than is sufficient to fill the capillary space between the slide and cover. The white corpuscles in the field of the microscope should then be counted, or an estimate made of the proportion of white to red corpuscles.

Several "fields" should be averaged before arriving at an opinion. This is but a rough method, and for more accurate determination a variety of tubes and slides have been devised. The capillary apparatus of Dr. Malassez is so constructed that one volume of blood diluted with one hundred volumes of a ten per cent. solution of sulphate of soda, to facilitate enumeration and prevent coagulation, is placed in a capillary tube adjusted on a glass slide so as to indicate a definite cubic capacity for a given length, which relation is marked on the slide by the instrument-marker. Then, by means of an eye-piece micrometer, divided into squares, the actual number of corpuscles, white and red, can be counted, and on multiplying by one hundred for the dilution used, we have the figure desired. Hayem and Nachet employ a slide having a glass ring one-fifth of a millimeter in depth cemented on it. A drop of blood diluted as above is placed in the cell

and covered with a flat glass cover. As soon as the corpuscles have settled to the bottom, the number in a definite area is counted. If the area chosen is one-fifth of a square millimeter, we have, of course, one-fifth of a cubic millimeter of diluted blood ready for enumeration by aid of the ocular micrometer divided into squares as before.

Changes in the appearance of the globules, white or red, should be noted, even though such changes are due to physical causes, as crenated margins, not running together in rouleaux, etc. Minute particles of bioplasm (microcytes) are sometimes seen, appearing as granular debris, whose significance is unknown. In pernicious anæmia globular cells, deeper in color and smaller than ordinary red globules, have been observed. In a case reported by Dr. Mackenzie the number of red disks was but 18.6 per cent. or 930,000 to the cubic millimeter, instead of 5,000-000 (page 187).

In the disease known as malignant pustule, splenic fever, anthrax, etc., a short, straight, motionless rod, about as long as the width of a blood-corpuscle, has been found in the blood, and is definitely related to the activity of the virus. It is called *Bacillus anthracis*, and resembles a common and harmless one found in infusions of hay, etc., the Bacillus subtilis, although the latter is endowed with motion.

In relapsing fever, during the paroxysm and relapse, but not in the interval, *Spirilla* are found in the blood. They are minute spirals of great tenuity, and are from two to six times the breadth of a blood-corpuscle.

The *Filaria sanguinis hominis* is found in the blood and urine of persons affected with a certain form of chyluria. It is about the breadth of a blood-cell, and $\frac{1}{7}\frac{1}{5}$th of an inch in length. It exhibits active wriggling movements.*

* Finlayson's Clinical Diagnosis.

Dr. Cobbold states that its larval state is passed in the stomach of the mosquito.

Dr. Beale has found cells similar to white corpuscles, but larger, in cases of cholera and of pyæmia. Many of these were too large to pass the capillaries.

The tendency of cells to adhere is thought by Beale to depend on a reduction of the amount of water. He observed such tendency to be increased after watery evacuations by Epsom salts.

Dr. Coupland described corpuscles, of a red color, $\frac{1}{4\,5\,0\,0}$th of an inch in diameter in blood from a case of Addison's disease. They disappeared as the patient improved.

Dr. Lostorfer, of Vienna, professed to be able to distinguish syphilitic blood by the presence of peculiar bright bodies in from one to five days after it had been taken from the patient. The drop of blood on a slide, covered with thin glass, is placed under a bell-glass arranged as a moist chamber. In from one to five days, in addition to vibriones, bacteria, and sometimes sarcina, there appeared these bright bodies, some at rest and some vibratile. Many of the larger ones were seen to increase by budding. He calls them syphilitic corpuscles.

Epithelial elements from the lining of the bloodvessels have been seen in the blood. Cancer-cells may in this way be transferred to distant parts. Epithelial cells becoming impacted in the smaller vessels may give rise to thrombosis and abscesses, as in puerperal and pyæmic fever.

Dr. Beale's researches upon the cattle-plague led him to believe that particles of germinal matter (contagium) introduced from without into diseased blood, and the products of their decay, may give rise to local congestions and various eruptions, as boil, carbuncle, and pustule.

Dr. Salisbury thinks that rheumatism may be detected long before the appearance of active symptoms by the excess of fibrin deposited in a drop of blood. He states

that cholesterin or nerve-fat may be seen in blood which has been kept from one to three days, and that variations in this, seen under the microscope, may throw light upon disordered mental and nervous functions. He claims that carbuncle, intermittent fever, enteric fever, and small-pox are produced by fungi in the blood, which he names respectively Crypta carbunculata, Gemiasma viridis, Byolysis typhoides, and Ivy variolosa.

The examination of blood in disease requires patient care and the employment of high powers, not less than 1000 diameters. As a field for original investigation, this subject affords a most tempting opportunity to those who have the leisure and skill to pursue it. The time may come when more may be known of a patient's disease by an examination of a drop of blood under the microscope than is possible in any other way.

In medico-legal inquiries the decision whether a blood-stain is of human blood or of one of the lower animals is one requiring exceptional skill, if, indeed, it is at all practicable. The differences given on page 187 are easily enough seen, but the red disks in a dog, a rabbit, etc., so nearly approach those of human blood in size, and the appearance of corpuscles in the same drop varies so much under high powers, as to lead to doubtful testimony before a jury. Dr. J. G. Richardson believes it quite possible to distinguish human blood, but at present few microscopists agree with him. In a doubtful case it would be well to scrape off from the slide half of the drop of suspected blood, replace it with undoubted human blood, and photograph the disks, so that one-half in the field of view would be known and ready for comparison with the other half.

To detect the red corpuscles in a blood-stain, it is well to soften the clot with glycerin diluted with water to the specific gravity of serum, or a one per cent. solution of salt may be used. If this fails, an attempt may be made

to obtain hæmin crystals. A portion of the supposed blood is placed on the slide, and a drop of water containing a trace of salt is added. A thin glass cover is applied, and a little glacial acetic acid is allowed to flow under and mix with the blood. Heat is applied until the mixture almost boils. The slide is then placed under the microscope, and the rhomboidal crystals may be observed with a high objective.

For microspectroscope appearances, etc., see page 102.

The guaiacum test, as it is called, depends upon the ozone in the hæmaglobulin of the blood causing a bluish tint in the solution of guaiacum. The tincture is made by dissolving one part of the resin in six parts of alcohol of eighty per cent. The bottles are to be only half filled, so that the tincture may be in contact with the air. Strips of white blotting-paper are soaked in this and the alcohol allowed to evaporate. A weak solution of blood dropped on the paper produces a blue color. This is only valuable as a negative test, since other substances give the same reaction. If the color is obtained, blood is not present.

EXAMINATION OF URINE.

Healthy urine contains a variety of organic and inorganic substances, as urea, uric acid, alkaline and earthy salts, animal excretine, vesical mucus, and epithelial cells. A drop or two evaporated on a glass slide will show the crystallized matters, consisting of urea, urate of soda, oxalate of lime, phosphates, and sulphates.

In examining urine for the purpose of diagnosis, it is necessary to be familiar with the appearance of the various crystals found in urine, as well as of accidental substances which are likely to be met with, as fragments of wool, hair, feathers, cotton, silk, and flax, particles of starch, epithelial cells, sand, vegetable fibres, etc. Igno-

rance of the microscopic appearance of these common things has led to ludicrous mistakes.

The amount of urine passed in each twenty-four hours varies from 20 to 50 ounces, holding in solution from 600 to 700 grains of solid matter. The amount, both of solids and fluids, varies according to the amount of fluids imbibed, the action of the skin, etc. The quantity of urine should be considered in relation with its specific gravity, since diminished urine with greater specific gravity may occur in diarrhœa, etc., and imbibed fluids may cause greater quantities with lessened specific gravity.

The average specific gravity of healthy urine is 1.020. It may be measured by means of the specific gravity bottle, or with the urinometer, a loaded glass bulb with graduated stem. According to Dr. G. Bird, each degree of the urinometer represents 2.33 grains of solids in 1000. Thus specific gravity 1.020 represents 46.60 grains solid matter, and 953.40 water in 1000 of urine.

Another table of Dr. Bird's shows that the specific gravity figures indicate nearly the amount of solids in each fluid ounce. Thus 1010 shows 10 grains of solids, 1020 about 20 grains, etc. Yet this is only approximate.

High specific gravities (above 1025) are found in diabetes (from sugar), in concentrated urine from fevers or other causes, in acute renal dropsy, and sometimes from large quantities of albumen in solution. Low specific gravities (below 1015) occur when the quantity is excessive, especially in diabetes insipidus, in lardaceous disease of the kidney, and chronic cases of Bright's disease.

UREA.

Urea is the vehicle by which nearly all the nitrogen of the exhausted tissues is removed from the system, and its retention is often attended with fatal uræmic poisoning of the blood. The quantity naturally eliminated de-

pends largely upon the amount taken in as food, but may be stated generally as from 400 to 500 grains a day, or 3½ grains per pound weight of the body. The specific gravity of the urine usually gives an indication of the quantity of urea excreted, since it is about one-third of the amount of solid matter.

If urea be suspected in excess, a drop of urine (concentrated and cold) may be put on a slide and a drop of nitric acid added. On covering with thin glass and placing under ¼-inch objective, the characteristic rhomboidal crystals of nitrate of urea will be seen (Plate XXVI, Fig. 240).

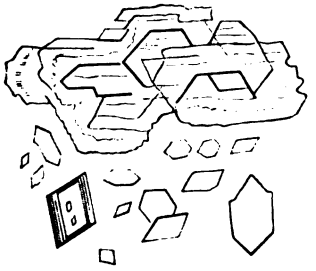
Volumetric analysis is the best means of ascertaining the quantity of urea as of other chemical ingredients, but this falls rather within the province of the professional chemist than of the microscopist. The practitioner may estimate approximately by weighing the crystals of nitrate of urea formed by adding nitric acid to double the quantity of urine which has been concentrated to half its bulk.

CHLORIDES.

The chlorides are always present in normal urine. They are diminished, and sometimes nearly suppressed, in several febrile diseases, especially in pneumonia. The quantity may be roughly estimated by acidulating the urine with a few drops of nitric acid, and then adding a strong solution of nitrate of silver. The density or abundance of the precipitate, as compared with a sample of normal urine, indicates the quantity; or the precipitate may be weighed after being dried and fused in a porcelain capsule. Albumen, if present, must be separated before testing for chlorides, as it is also thrown down by nitrate of silver.

PLATE XXVI.

FIG. 240.



Nitrate of Urea.

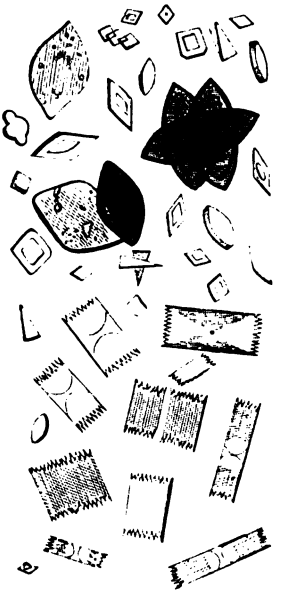
FIG. 241.

Tube-casts.

FIG. 242.

Urate of Ammonia.

FIG. 243.



Uric Acid.

FIG. 244.

Uric Acid.

FIG. 245.

Uric Acid—re-precipitated.

BILE.

Bile in urine, if present in large quantity, can be recognized by the eye. In testing for albumen by nitric acid, the greenish color produced by bile will also attract notice. A more delicate test consists in placing a drop or two of urine and a drop or two of strong nitric acid near together on a white plate and allowing one to run into the other. As the acid mixes with the fluid, a play of colors, commencing in green and terminating in red, passing through various shades, will be observed.

Bile in urine indicates jaundice, and may aid in the differential diagnosis of discolorations of the skin and conjunctiva due to other causes. It may show an incipient jaundice before the tissues are generally affected, and its disappearance may afford evidence that the attack is passing off when the effects of jaundice may be visible elsewhere.

ALBUMEN.

In suspected albuminuria, samples should be examined which were passed at different times of the day, as before eating in the morning, and after eating in the evening. Care should be taken to have clean bottles, test-tubes, etc. The urine should be subjected to a double test, by boiling in a test-tube and the subsequent addition of a drop or two of nitric acid, and by the addition of strong nitric acid to a separate portion of the cold urine. In the latter test a cloudy ring of albumen appears at the junction of the two fluids.

The quantity of albumen may be estimated sufficiently for clinical practice by allowing the precipitate formed on boiling to subside for a definite time,—twelve to twenty-four hours,—and observing how much of the tube is occupied, as a half, a fourth, an eighth, etc.

Sometimes albumen is due to the presence of blood, pus, etc., as revealed by the microscope, and its significance must be considered under these terms. Many acute febrile diseases give rise to albuminuria, which may be regarded as one feature of the general disturbance rather than of local importance.

After the primary fever of scarlatina, and occasionally after small-pox, enteric fever, and erysipelas, albuminuria is present. It is not infrequent in pregnancy and the puerperal state, and though not necessarily, yet often indicates possible danger of convulsions during labor, chronic renal disease, etc.

Chronic chest complaints are often complicated with albuminuria, which has an important bearing on prognosis. In such cases it may be only one of the indications of a temporary general venous congestion, or it may indicate a nephritis established through long-continued congestion, or the renal disease shown by the albuminuria may be primary and the thoracic affection a complication. In all dropsies the presence of albumen is important. Genuine renal dropsy rarely occurs without it, yet it may be secondary and due to pressure on the renal veins

Albuminuria in acute or chronic renal disease must be considered in connection with other urinary contents, as tube-casts, epithelium, etc., and with alterations in quantity, specific gravity, etc.

The significance of albuminuria in nervous diseases is variable. It may be an effect of nervous disturbance, as after a convulsion or from some lesion of the brain, or the renal disease may be the cause of the nervous affection, as in uræmic coma or convulsions, etc.

We must look for albumen in the urine in many chronic and constitutional affections, and transiently after the use of blisters, etc. Where there are so many sources of albuminous urine we must be guided by the general symptoms, and particularly the presence of microscopic

deposits, derangements of quantity, and density in the urine.

SUGAR.

Urine should be tested for sugar when diabetes is suspected, or when the quantity is excessive, or the specific gravity is high (above 1030). In some cases of cerebral disease, also, sugar appears in the urine. The urine should first be examined for albumen, since its presence is a serious complication of diabetes, and it may interfere with the reactions by the copper test. If present it should be removed by boiling and filtration. Boiling albuminous urine with crystals of sulphate of soda is said to render it suitable for the copper test, but the other way is best.

Copper Test—Trommer's Test.—The urine is mixed with a few drops of a solution of sulphate of copper in a test-tube; excess of liquor potassæ is then carefully added, enough to just dissolve the precipitate it first throws down; the mixture is then boiled, and if sugar is present a red precipitate of suboxide falls down. As errors occur from not using the proper proportions, the following test is preferred:

Fehling's Test Solution.—Sulphate of copper, 90½ grains; neutral tartrate of potash, 364 grains; solution of caustic soda (of specific gravity 1.12), 4 fluid ounces; add water to make up 6 fluid ounces. (Or 40 grams of sulphate of copper in crystals, 160 grams neutral tartrate of potash, 750 grams caustic soda, specific gravity 1.12; add water up to 1154.5 cubic centimeters. Each 10 cubic centimeters correspond to 0.05 gram of grape-sugar.)

A little of the test fluid is first boiled in a test-tube to see if it remains unchanged in color, since it is apt to alter by age. If unaffected, add a drop or two of the suspected urine. If sugar be present in quantity the color changes, and a yellowish or reddish precipitate falls. If no reaction occurs, add a little more urine, but less than the

volume of test fluid, boil it and cool; if no yellow or red suboxide falls, it is free from sugar. Prolonged boiling must be avoided, as well as boiling the urine before adding the test.

To determine the quantity of sugar by the copper test Fehling's solution is made of such strength that 200 grains (by measure) are completely reduced by one grain of diabetic sugar. The test fluid is boiled in a flask, etc., and a quantity of pure water equal to one or two volumes of test fluid poured in also. The saccharine urine, diluted with one volume urine to nine of water if sugar is abundant, is placed in a burette, graduated to grains, and is gradually added to the boiling copper solution till the blue color is quite discharged. The number of grains of urine consumed—representing one grain of sugar—is read off, and it is then a matter of calculation how many grains are contained in the ounce of urine, making allowance for the degree of dilution.

Fermentation Test.—This is sometimes more convenient or preferred from uncertain results of the copper test. A small tube is filled with suspected urine, a little fluid or solid (German) yeast is added, and the tube is inverted over a saucer containing urine and placed in a warm situation for twenty four hours. If sugar is present it undergoes fermentation, yielding alcohol and carbonic acid. The latter rises in the tube and displaces the liquid. The quantitative test by fermentation consists in determining the specific gravity of the urine before and after complete fermentation. It has been found, empirically, that one degree of specific gravity lost by fermentation corresponds with one grain of sugar per fluid ounce of urine.

Bismuth Test. Mix an equal volume of suspected urine with a solution of carbonate of soda—one part of the crystals to three parts water (or with half as much liquor potassæ). Put in a little basic nitrate, or subnitrate of bismuth, and boil. If sugar be present the bismuth be-

comes grayish or blackish from the formation of the suboxide or of metallic bismuth.

URINARY DEPOSITS.

Deposits from urine are either organic or precipitates from solution. The urine should be put in a conical glass of four or five ounces capacity, and kept free from dust for about twelve hours. A small portion of the sediment should then be taken up with a clean pipette and examined under the microscope on a glass slide covered in the usual way (page 77). A quarter of an inch objective will be found most generally useful.

To facilitate microscopical examination and diagnosis we add the following table from Richardson's *Medical Microscopy:*

I. A distinct deposit is seen in the urine.

A. This deposit is light and flocculent.

a. It occurs in albuminous urine, one yielding a coagulum with heat and nitric acid.

a. The microscope shows casts of the uriniferous tubules (transparent or granular cylinders $\frac{1}{5}\frac{1}{0}$th to $\frac{1}{1}\frac{1}{0}\frac{1}{0}\frac{1}{0}$th of an inch in diameter), either granular, epithelial, or hyaline,—*Bright's disease of the kidney.*

β. The microscope shows red blood-corpuscles (non-nucleated disks $\frac{1}{3}\frac{1}{5}\frac{1}{0}\frac{1}{0}$th of an inch in diameter), mixed with mucus,—*hæmaturia.*

γ. Leucocytes only are seen (nucleated corpuscles,—pus-corpuscles,—$\frac{1}{2}\frac{1}{5}\frac{1}{0}\frac{1}{0}$th of an inch in diameter),—*nephritis, cystitis, etc.*

b. The urine is not albuminous.

a. Leucocytes, epithelial cells from the bladder, and perhaps mucous casts of the tubules appear,—*irritation of urinary tract.*

β. Spermatozoa,—*if numerous, spermatorrhœa.*

γ. Fungous growths (cellular bodies $\frac{1}{4}\frac{1}{0}\frac{1}{0}\frac{1}{0}$th to $\frac{1}{1}\frac{1}{0}\frac{1}{0}\frac{1}{0}\frac{1}{0}$th

of an inch in diameter, often arranged in chains, still, or vibratile),—*pathological significance uncertain.*

δ. Hyaline and pale tube-casts (rare in non-albuminous urine),—*Bright's disease.*

B. Deposit dense, opaque, bulky.

a. Urine non-albuminous.

α. Microscopic deposit, granular simply,—*urates or phosphate of lime.* The former dissolve on heating.

β. Microscopic crystals, triangular prisms and their derivatives,—*triple phosphates.*

b. Urine albuminous.

α. Leucocytes only,—*nephritis, cystitis, etc.*

β. Crystals of triple phosphates, with leucocytes,—*chronic cystitis, perhaps calculus.*

C. Deposit granular or crystalline; small.

a. Urine albuminous.

α. Red blood-disks,—*hæmaturia.*

β. Cancer-cells (irregular, caudate, and oval, with large nuclei),—*carcinoma.* Mistake not epithelial for cancer cells.

γ. Tubercle corpuscles (non-nucleated, granular, oval bodies, about $\frac{1}{2000}$th of an inch in diameter),—*tuberculosis.*

b. Urine not albuminous.

α. Oxalate of lime crystals (brilliant octohedra, showing as squares marked with diagonal crosses, or more rarely as dumb-bells),—*oxaluria.*

β. Uric acid crystals (yellowish, lozenge-shaped, oval, barrel-shaped, etc.),—*lithuria.*

γ Microscopic spherules and dumb-bells, soluble in acetic acid with effervescence,—*carbonate of lime.*

δ Hexagonal crystals of cystin,—*cystinuria.*

ε. Sediment resembling uric acid, but soluble in hot water and mineral acids,—*xanthin.*

ζ. Sheaflike bundles or globular masses of acicular crystals, *tyrosin and leucin,—acute atrophy of liver?*

η. Hydatids, etc.,—*entozoa.*

II. Urine turbid, without distinct deposit.

A. Turbidity disappears on warming,—*amorphous urates.*

B. Cloudiness remains while heating.

α. Vibriones and bacteria present,—*putrefactive fermentation.*

β. Numerous minute molecules,—*chylous urine.*

III. A film on surface of urine.

A. Prisms of triple phosphates, usually with granular phosphates and spherules of urate of soda,—*phosphuria.*

B. Numerous small oil-globules, with triple phosphates,—*kiestin.*

EPITHELIUM.

The character of the epithelial scales will often show the locality of disease in the urinary tract (Fig. 142). *Renal epithelium* lying loose in the deposit is somewhat globular, and may sometimes be compared with that in the tube-casts in the same specimen. It bears quite a resemblance to pus-cells. It occurs in desquamative nephritis, and undergoes various changes, appearing atrophied, granular, or fatty. Sometimes large granular corpuscles occur with fatty epithelium, being altered cells themselves.

Cells from the bladder occur often as groups of tessellated cells of circular form—sometimes pyramidal. *Caudate epithelium* is found in the ureter and pelvis of the kidney, and may be caused by calculous pyelitis. *Large scaly epithelium* comes from the vagina.

MUCUS AND PUS.

Mucus is deposited as a flocculent cloud, entangling a few round or oval delicately granular cells, a little larger than a red blood-globule. In disease this increases and contains numerous ill-defined cells. A very thick glairy

deposit in disease of the bladder may be mistaken for mucus when it is pus altered by the action of carbonate of ammonia.

Pus is formed often from the germinal matter of epithelium, so that a small quantity in urine is not necessarily a sign of serious disease. In large quantities pus forms an opaque cream-colored deposit, which becomes glairy and tenacious by the addition of liquor potassæ. The addition of the latter will dissolve white urates, and serves to distinguish pus from them as well as from phosphates, which are little affected by it. The microscope, however, is the best test.

Purulent urine is usually acid if of renal origin (if tested immediately), and is alkaline and ammoniacal in suppuration from the bladder. Coexisting epithelium, etc., is often of value in determining the origin of pus. Pus-globules under the microscope, if long removed from the body, are granular and show from one to four nuclei when treated with acetic acid. In fresh pus-corpuscles, especially in warm weather, amœboid motion is often seen. In a late period of catarrh of the bladder but little epithelium may accompany the discharge, but crystals of triple phosphates occur generally in pus derived from the bladder.

The clinical significance of pus in the urine is quite varied. It may follow renal inflammation, and often appears in albuminuria following fevers and in renal embolism. Abscesses opening into the urinary tract, cystitis, cancer of the bladder, suppuration of the prostate, gonorrhœa, and gleet may all give rise to purulent urine. Accidental mixture from lochial or leucorrhœal discharges is also possible.

BLOOD.

Blood may sometimes be recognized by the eye in urine from its smoky or dingy tint, especially in blood from the

...dish-brown de-
...hibit the disks,
...hen we must be
...and other tests.
...general disease af-
...on some poisonous
...arides, turpentine,
...al affection of the
...e the general symp-
...dered, but sometimes
...may be a guide to the

...

...les with elongated tails,
...ealth, but nervous patients
... on account of them. Of
...ally and in large numbers
... spermatorrhœa.

...UNGI, ETC.

...often appear in alkaline and
... fungus (*Torula*), or yeast plant,
...are even minute traces of sugar.
...ng growths are also frequent.
...able tube-casts. Spores of globular
... for blood-corpuscles. Sarcinæ, or
..., dividing into groups of four and
...times found in the urine of dyspep-

TUBE-CASTS.

...ongestion and inflammation a coagu-
...used into the tubes of the kidney,
...ould of the tube. This may be ejected,
...us, blood, epithelium, or other material

with which it is associated. In Bright's disease these casts, in addition to albuminous urine, assume considerable clinical importance. In the acute form of the disease the cylinders or casts are fibrinous, with blood, mucus, or pus cells, and epithelium. Towards the close the casts become homogeneous or hyaline. In chronic desquamative nephritis the cylinders are without blood, and towards the end waxy or fatty, often containing many oil-globules (Plate XXVI, Fig. 241). The specimen of urine examined for casts should have settled for several hours, and the drop of sediment examined should be carefully focussed and illuminated. The casts are of various sizes, those of very large diameter indicating dilation of the renal tubules.

In bloody or purulent urine tube-casts point out a renal element in the case. They do not always indicate Bright's disease, as they may be associated with the irritation of a calculus, and are sometimes found in jaundice without serious renal trouble or albuminuria.

CRYSTALLINE AND AMORPHOUS DEPOSITS.

Uric Acid.—Crystals of uric acid may often be recognized as a red sand, lying at the bottom or on the sides of the vessel, or entangled in mucus. They may be yellow, red, or brown, from coloration by urinary pigment. Their microscopic forms are various, but are usually some modification of the rhomb. Thus they may be rhomboid tablets with obtuse angles, or the shape of a whetstone (Plate XXVI, Fig. 242). When slowly precipitated, uric acid may form druses of four-sided prisms (Plate XXVI, Fig. 243). When precipitated from fresh urine by the addition of muriatic acid, the crystals are large and often of various shapes. They may be tested by dissolving in potassa and reprecipitating by muriatic acid, when they assume the shape of Fig. 244, Plate XXVI. Crystals of uric acid may occur as a film as well as a deposit. They originate from tissue-waste, excess of nitrogenous food,

defective assimilation, congestion of the kidney, or chronic disease of the respiratory organs.

Urates or *lithates* are salts of uric acid combined with soda, potash, or ammonia, the exact composition being difficult to determine. Such sediments are very common. They are generally amorphous, but sometimes crystalline (Plate XXVI, Fig. 245). The urate of soda presents the form of globules with projecting spiculæ. The color is various, from a light pink to brickdust color. It is deposited in all concentrated urine, and is often a "critical discharge" in fevers, etc. It is found in gouty concretions, and dissolves with heat and acids.

Phosphates appear in two forms, crystalline and amorphous. The crystalline are the crystallized phosphate of lime, and the ammonio-magnesian (or "triple") phosphate. The latter is most common, and may appear in any decomposing urine. It may be precipitated from fresh urine in stellate crystals (Plate XXVII, Fig. 246) by adding ammonia. More slowly deposited from alkaline urine, or in disease, the crystals are prismatic, generally triangular, with truncated ends. Sometimes the truncated ends are bevelled, and the various lengths of the prisms give rise to a variety of forms (Plate XXVII, Fig. 247).

Triple phosphates are generally thought to proceed from disintegrated albuminous, and chiefly nervous matter, but their clinical importance is not fully settled. They are found in cases of nervous depression, various forms of dyspepsia, shock of the spinal cord, irritation of the bladder, etc.

In highly alkaline urine the triple phosphates are often accompanied with pus and phosphate of lime. The latter occurs as minute granules or dumb-bells, or in groups of crystals (Plate XXVII, Fig. 248). They are dissolved by acetic acid, which distinguishes them from uric acid.

Oxalate of lime is deposited in small octohedra, generally appearing under the microscope as minute squares with crossed lines proceeding from the angles, the upper

angle being next the eye (Plate XXVII, Fig. 249). Dumb-bell forms and circular or oval crystalline masses are sometimes seen.

Oxalate of lime is found as a urinary deposit in various conditions, as in pulmonary and dyspeptic affections. It is usually associated with hypochondriasis, and in cases of overfatigue, particularly from mental work, it is common. The train of nervous and dyspeptic symptoms with which it is associated have been supposed to indicate an "oxalic acid diathesis," and have been named "oxaluria." Its association with calculi renders it interesting to the surgeon.

Chloride of sodium never crystallizes from fluid urine. On evaporation it occurs in stellar form or in cubes (Plate XXVII, Fig. 250). The presence of urea sometimes disposes it to assume the form of a regular octahedron. The amount of this excretion in typhoid fever and in inflammations of the respiratory organs is greatly diminished. It is absent in commencing hepatization of the lung, but returns on resolution of the inflammation (see *Chlorides*, page 302).

Cystin crystallizes in characteristic six-sided plates (Plate XXVII, Fig. 251). It contains twenty-six per cent. of sulphur, and is considered a product of decomposition. It is often associated with calculus. Some regard it as indicating a strumous and ill-nourished system.

Carbonate of lime occurs rarely in human urine, but is common in that of the horse. Its form is that of a spherule made up of acicular crystals. It effervesces in acetic acid.

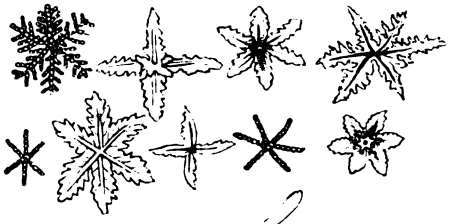
Tyrosin, in sheaflike or globular masses, sometimes occurs in typhus and in atrophy of the liver.

III. PUS AND MUCUS IN DIAGNOSIS.

We have already considered the bioplasts of pus and mucus as identical in character with other leucocytes, as

PLATE XXVII.

FIG. 246.

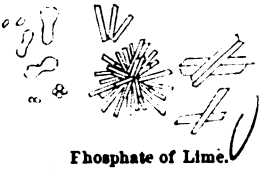


Ammonio-phosphate of Magnesia.

FIG. 247.

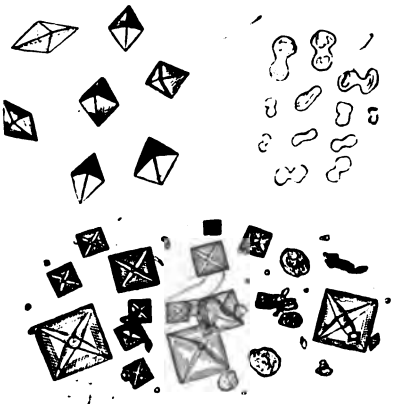
Ammonio-phosphate of Magnesia.

FIG. 248.



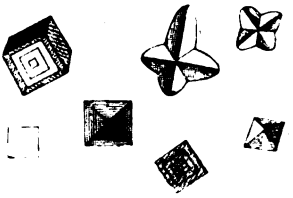
Phosphate of Lime.

FIG. 249.



Oxalate of Lime.

FIG. 250.



Chloride of Sodium.

FIG. 251.

Cystine.

FIG. 252.

Salivary corpuscles, epithelial scales and granules.

the white blood-cells (see pages 189 and 309). They are easily seen by the microscope in a drop of purulent matter placed on a slide and covered by thin glass. Pus-corpuscles shrink in size on being placed in liquid of greater specific gravity than serum, and are destroyed by the action of caustic alkalies so as to be changed into a tenacious glairy mass. Dilute acetic acid causes them to swell and become transparent, exhibiting from one to four nuclei. Bacteria and their germs (microzymes) are often seen with pus, and indicate commencing decomposition.

According to Dr. Beale, the figures and descriptions generally given of pus represent dead, not living pus. He recommends a little pus to be taken from suppurating skin or mucous membrane and examined at once, in order to see the projections from the bioplasts, by the detachment of which they multiply. He considers the "mucous corpuscle" to be nothing more than an imperfect epithelial cell surrounded by the viscid mucus formed by it. This may grow rapidly, and the resulting particles become true pus-corpuscles.

Richardson regards the difference between pus and mucus to be that "the liquor muci is a *secretion*, which, having been acted upon by the germinal matter of the epithelial cells covering the basement mucous membrane, is not albuminous, while the liquor puris is an *exudation*, which contains albumen, that may be recognized by appropriate tests."

IV. EXAMINATION OF MILK.

Examination of human milk may sometimes aid in diagnosis, as in contusions of the breast, incipient mastitis, and in the diarrhœa and innutrition of infants. The origin of milk may be elucidated by the remarks on lactification on page 233.

A thin stratum of milk should be examined with a power of from 200 to 400 diameters, and an estimate

made of the milk-globules, as in the case of the blood-corpuscles (page 296); or the sample may be compared with a specimen known to be healthy.

Impoverished milk is known by the small number and size of the globules. Colostrum or "exudation" corpuscles are numerous shortly after childbirth. In engorgement of the breast the globules aggregate in masses, and sometimes from inflammation, blows, etc., blood and pus may be found. Starchy adulteration may be detected by the addition of iodine. Richardson speaks of fibrinous casts of the lacteal ducts occurring after puerperal mastitis, and Beale of minute particles of contagious bioplasm in the milk of a cow suffering from cattle-plague, and considers it possible that typhoid fever, etc., may be thus propagated.

V. SALIVA AND SPUTUM.

Besides the epithelium of the mouth, saliva holds in suspension certain oval or spherical bodies, probably derived from the glandular follicles, called "salivary corpuscles" (page 189).

Dr. Richardson considers them identical with leucocytes. Beale supposes them to be concerned with the conversion of starch into sugar, which occurs from the action of the saliva. The peculiar dancing movement of the granules of these corpuscles needs a $\frac{1}{12}$th of an inch object-glass, or one even higher, to see them well.

In examining sputum a small piece should be placed on a slide and teased out with needles, if necessary, in glycerin and water, or some indifferent fluid. We may expect to find mucus entangling air-bubbles and pavement epithelium from the mouth (Plate XXVII, Fig. 252). The observer should, however, be familiar with the appearance of fragments of food, starch, epithelium from the various parts of the air-passages, fungi, etc.

In catarrhal affections ciliated epithelium from the

nasal or respiratory passages may be seen, and perhaps molecules of fat, pus-globules, blood, and "inflammatory corpuscles." In phthisis the decaying lung may be early detected by the fibres of elastic tissue from the walls of the pulmonary vesicles. The sputa should be first liquefied by boiling a little while in an equal bulk of caustic soda, then allowed to settle in a conical glass, when a small quantity may be removed to a glass slide, covered with thin glass, and placed under the microscope.

The occurrence of fungi in sputum is to be expected whenever there is decay. The *Leptothrix buccalis*, one form of *penicillium*, is common on old epithelial scales of the mouth, and in the latter stages of phthisis the sputa will often show fungi in various forms of development.

In catarrhal pneumonia we may find fibrinous casts of the alveoli of the lungs and epithelial elements, chloride of sodium, etc. Hydatids are sometimes expectorated in sputum, the appearance of the hooklets of the echinococci being quite characteristic. Scales of cholesterin and blood-crystals may also occur, as well as calcareous concretions and dark melanotic masses.

Richardson states that associated matters may indicate the source of blood in sputum. Thus associated salivary corpuscles might show hæmorrhage within the mouth, amœboid leucocytes, hæmorrhage in the fauces or trachea, starch-granules and particles of food, hæmatemesis, and coagulated casts, pulmonary hæmorrhage.

VI. VOMITED MATTERS.

Microscopic examination of vomited matters reveals muscular fibres, starch-granules, oil-globules, and shreds of vegetable tissue, according to the diet of the patient. Crystals of margarin, etc., are often seen. Blood, pus, etc., may be recognized if their structure be not destroyed by the digestive fluids.

Isolated specimens should be picked out with forceps

and scissors, or the vomit should stand some time in a conical glass and a little of the deposit removed with a pipette.

Torula and other forms of fungi are often seen in vomited matters. The vomit containing the *sarcina ventriculi* generally ferments like yeast.

The color of the "coffee-grounds vomit" is due to dark-brown pigment, probably the altered coloring matter of blood.

Some specimens of cholera vomit showed numerous flocculi, consisting of epithelium. The clear fluid of pyrosis contains only a little epithelium and a few small oil-globules. The green vomit depending on bile contains cylindrical epithelium from the gall-ducts, scaly epithelium, flakes and masses of biliary coloring matter, and fat-globules.

Dr. Beale records a case of the detachment of flakes of stomach epithelium in a case of scarlet fever.

Biliary matters, as cholesterin, etc., and even small gall-stones, have been rejected by vomiting.

VII. INTESTINAL DISCHARGES.

Microscopists are not unfrequently called upon to examine dubious matters passed from the bowels. Dr. Bennet describes one case of yellowish pulpy masses passed with the stools as consisting of undigested potato skins, and another made up of a network of confervoid growths developed in the intestinal canal. In one case, seen by the author, tormina, etc., were produced by skins of grapes; another case exhibited the skin or testa of a large seed, as the tamarind. These instances show the necessity of the observer being familiar with various botanical and histological appearances.

Blood-globules in fæces retain their natural appearance in inverse proportion to the distance of the hæmorrhagic point from the anus, so that quite fresh blood will indicate

hæmorrhoids, fistula, etc., while more disintegrated disks indicate effusion further up the intestinal tube.

Mucous casts or coagula of albuminous matters are not very uncommon, either in flakes or tubular casts. The mucus entangles epithelial cells, usually from the large intestine. In typhoid fever crystals of triple phosphates, altered blood, bacteria, and various fungi may be found in the fæces, and the stools of cholera patients contain large quantities of cylindrical epithelium, so that the white flocculi are almost entirely composed of it.

Elastic fibres, exhibiting transverse striæ like those of the ligamentum nuchæ of the giraffe, are sometimes found arising, in all probability, from incipient decomposition of ingesta.

Larvæ of insects may sometimes be passed alive from the bowels, as well as be ejected from the stomach. The various forms of intestinal worms in their various stages of development may also be met with. In some instances the microscope is needed to distinguish between suspected worms, or portions of worms, and accidental products. Fatty matter in the stools, sometimes semisolid, is usually attributed to derangement of the pancreas.

VIII. VAGINAL DISCHARGES.

The diagnostic value of discharges from the vagina, either uterine or vaginal in their origin, has been yet but little studied, and presents a field of special interest in gynæcology. The discharge should be examined while fresh and without the addition of water or other fluids if possible. Should fluid menstrua be really necessary, indifferent fluids only should be used.

The menstrual discharge will be likely to contain young and old epithelial scales and blood-globules. In dysmenorrhœa considerable patches of the epithelial membrane desquamate, and even entire casts of the uterus or vagina

have been separated. The diagnosis between dysmenorrhœa and abortion may be determined by a microscopic examination of such fragments, since the villi of the chorion can be thus recognized if present.

In leucorrhœa old epithelial cells, loaded with fat, will be seen, with imperfectly formed epithelium and pus globules. Beale states that the development of pus-corpuscles from the bioplasts of epithelium may be successfully studied in leucorrhœal discharges. Sometimes blood-globules will be seen altered by exosmosis, etc.

The white gelatinous discharge from the os uteri, often seen in uterine catarrh, consists of mucus with epithelial elements.

Fibrous, epithelial, and cancerous tumors or ulcers may sometimes be recognized by their microscopic elements, yet it must be remembered that altered epithelium may be readily mistaken for the elements of cancer, etc.

The *Trichomonas vaginalis* (Donne) is common in the yellow acrid mucus of vaginal blennorrhœa. It is a roundish ciliated animalcule, and may be distinguished from ciliated epithelium by the elongation of the anterior end, which is sometimes drawn out into a long filament or flagellum.

The epithelium from the Fallopian tubes and uterus is columnar and ciliated, while that of the vagina is squamous, with large cells.

Accidental products may also be discharged from the vagina, as well as from other cavities. In one case I found a number of living crustacea (*Gammara-pulex*), which occasioned great pruritus, but were dislodged by injections of sweet oil.

Dr. Sims has shown how the microscope may aid in the cure of sterility, since the uterine cervical mucus needs to be slightly alkaline. If habitually acid it destroys the spermatozoa.

CHAPTER XV.

THE MICROSCOPE IN ÆTIOLOGY.

THE study of ætiology, or the knowledge of the causes of disease, although so important a branch of practical medicine, needs the careful and united efforts of many observers to be classified and recorded before approaching perfection. Here, also, the microscope will be found an important aid. The numerous external causes of disease, such as physical or organic impurities in the atmosphere, soil, water, and food, vegetable or animal parasites, and "disease germs," with their relation to epidemic or endemic disorders, all require skilful use of the microscope.

I. EXAMINATION OF THE AIR.

The pressure, temperature, moisture, and electricity of the air, all of which are important in considering causes of disease, require other modes of investigation, but the microscope may be reasonably expected to aid in inquiries concerning mechanical, chemical, or organic impurities.

Many methods have been proposed for collecting matters suspended in the atmosphere. A shallow dish containing distilled water, or a clean glass vessel containing ice, so as to condense the atmospheric moisture with its impurities on the outside, and allow it to trickle into a conical receiver, have been used. Glass plates moistened with glycerin and exposed to the air are still better. The aeroscope of Dr. Maddox is a funnel-shaped tube turned to the wind by a vane. The narrow end of the tube is opposite a slide moistened with glycerin.

Many absurd "discoveries" have been paraded respecting matters in air and water, yet careful observation will

reveal valuable facts. Solid fragments of carbon or silex, etc., starch grains, filaments of cotton, flax, wool, silk, etc., spores of fungi, animal and vegetable debris, etc., all require considerable familiarity with microscopic objects in general, without which no one should undertake such investigations.

Minute living particles of bioplasm, either ordinary pus or what Dr. Beale calls "disease germs," should be diligently sought for under high objectives.

Pollen-grains are often found in the air. In Schuylkill County, Pa., in the summer of 1858, after a rain-shower, a yellow scum of pollen covered all the pools, and was traced over a tract of fifty by twelve miles. Showers of "flesh" or "blood" have been described in newspapers, which were probably varieties of *Nostoc* (page 151), or pigment bacteria (page 326).

The subject of bacteria germs in the air has lately acquired great interest from the success of the antiseptic method now generally pursued in large surgical operations, and first introduced by Mr. Lister. This will be considered under the head of disease germs.

The examination of the breath of men or animals may be made by means of glycerin on glass slides, or by breathing through a glass tube containing cotton-wool, which may afterwards be washed with dilute glycerin. Epithelial cells, oil-globules, fragments of food, soot, fungi, etc., may thus be detected, or the expired air may be tested for ammonia with hydrochloric acid.

II. EXAMINATION OF SOIL AND WATER.

The soil may be examined both chemically and microscopically according to the methods given on former pages of this work. The importance of such examination will be plain in many cases of local diseases. It is stated that the mortality caused by murderous epidemics in England

has been greatly diminished since the systematic building of sewers and the prohibition of pitlike privies in towns.

Dr. Salisbury's observations on the growth of certain fungi as the cause of malarious fevers, although requiring further confirmation, suggest a very pertinent line of inquiry.

Drinking-water may be vitiated by organic matter and its chemical products, as ammonia, chlorine, and the nitrates. Wagner states that to be drinkable it must not contain in 100,000 parts more than 0.4 parts of nitric acid, 0.8 parts of chlorine, and 5 parts of organic matter. Boiling does not improve such water. It is generally made impure by sewage, and produces gastric and intestinal diseases, and perhaps typhoid fever.

III. EXAMINATION OF FOOD, ETC.

The adulteration of food has long been a question of interest, and has been investigated by a host of observers. Dr. Hassall's voluminous researches, however, leave little to be desired. He states that "in nearly all articles, whether food, drink, or drugs, my opinion is that adulteration prevails. And many of the substances employed in the adulterating process were not only injurious to health, but even poisonous." Dr. Hassall's work, *Food and its Adulterations*, should be used by all who inquire into this subject, which is too voluminous to be considered here in detail. Familiarity, however, with the subjects already discussed in this work will qualify the observer for such examinations. Wheat-flour may be examined by adding a little water, and then a few drops of a solution of potash (one part liquor potassæ to three of water). Granules of potato-starch swell by this means to three or four times their natural size, while those of wheat-starch are scarcely affected by it. Comparisons of different kinds of starch under the microscope will guide in many other

investigations. Adulteration of flour with alum, etc., may be detected by dissolving the alum and recrystallizing under the microscope.

Coffee is adulterated with chiccory, wheat, corn, etc.; tea with foreign leaves, Prussian blue, clay, etc.; chocolate with brickdust, peroxide of iron, animal fat, etc.

IV. PARASITES.

Parasites are animal or vegetable organisms which live temporarily or permanently upon or within another organism for their nourishment and development. Casual visitors for the sake of moisture, warmth, or products of decomposition (as many fungi and infusoria) are called pseudo-parasites. Van Beneden distinguishes between messmates which are nourished in common, mutualists which live on and serve each other, and parasites which live at others' expense.

In this department of science the student will do well to consult Cobbold's magnificent work on *Entozoa*, and two of the recently published international scientific series of books, viz., *Fungi*, by Cooke and Berkely, and *Animal Messmates and Parasites*, by Van Beneden.

The plan of Wagner, in his *Manual of General Pathology*, is followed in the present outline, so far as classification is concerned.

I. VEGETABLE PARASITES OR EPIPHYTES.

I. FUNGI.

The general character and development of fungi have been described at page 136. The subject of polymorphism also has been referred to as indicating the uncertainty of distinguishing genera and species. Cooke reminds us, however, that polymorphism can only be based upon actual organic continuity, the observance of which in such minute organisms is necessarily difficult.

A. DUST OR GERM FUNGI, CONIO OR GYMNOMYCETES.

1. *Mycoderma* (Cryptococcus).—The beer-yeast (*Micrococcus*, or *Torula cerevisiæ*) consists of round or oval colorless cells containing one, and sometimes two bright nuclei resembling oil-globules. New cells arise from these by budding. No proper filament or mycelium is formed.

The milk-yeast (*Oidium lactis*) can grow fungus-like if submerged, while on the surface is a mycelium of articulated filaments from which shoots grow up, whose cells separate easily.

Schwann, Pasteur, etc., consider the yeast-fungi as organisms produced by specific germs, while others regard them as spores, which in the atmosphere fructify in other forms.

B. FILAMENTOUS FUNGI, HYPHOMYCETES.

The mycelia of these are lengthened tubular cells, often branching. The spores originate within or at the end of filaments. Here belong the fungus of the muscardine of the silkworm (*Botrytis bassiana*), the potato disease (*Fusiporium solani*), the grape disease (*Oidium tuckerii*), mould, and the fungi occurring in diseases of skin and mucous membranes.

1. *Penicillium glaucum*, common mould or pencil mould, forms most of the mould occurring upon vegetable decomposing substances. The fruit-bearers rise from a branched colorless mycelium. The points are tufted and bear spherical conidia.

2. *Aspergillus glaucus*, or green mould, is often found with the foregoing. The fruit-filaments expand into club-shaped basidia. The spores are greenish.

3. *Mucor mucedo* and *Mucor racemosus* are found on excrement and old articles of food. The bladder-like swollen fruit-hyphen (columella) rises from a branched

filamentous mycelium, which becomes septate with age. The spores are set free by breaking of the wall of the sporangium.

C. CLEFT FUNGI, SCHIZOMYCETES (*bacterium, micrococcus*).

The term schizomycetes is given from the great fragility of the formation. They are cells without chlorophyll, of various forms, which increase exclusively by transverse division. The cell-membrane is not destroyed by potassa, nor by acids, and resists decomposition for a long time.

1*st Group. Spherobacteria.*—Globular bacteria (Pasteur's *Monas* or *Mycoderma*. Ehrenberg's *Monas corpusculum* and *prodigiosa*. Hallier's *Micrococcus*).

Spherical or oval cells, without granular contents, possessing a double contour, and becoming moniliform by division. Often difficult to distinguish from granular detritus.

1*st Genus. Micrococcus* (Cohn).—Bells colorless or nearly so, very small, united into short moniliform filaments of two or more members (*mycrothrix*, *torula-forms*), or into many-celled families, balls, or colonies, or into mucous masses (*zoogloa-forms*, *mycoderma-forms*). No movement.

(1.) Pigment bacteria. Appearing in colored jellylike masses.

a. Coloring matter, insoluble, red and yellow.

1. *Micrococcus Prodigiosus* (*Palmella prod.*).—Cause of the seeming blood-spots which sometimes appear during moisture on wafers, bread, potatoes, etc.

2. *M. luteus.*

b. Coloring matter, soluble. *M. aurantiaceus*, *chlorinus*, etc.

(2.) Zymogenic globular bacteria.

3. *Micrococcus Urea.*—Ferment of urine.

(3.) Pathogenic globular bacteria. "Ferments of contagion."

4. *M. vaccinæ.*

5. *M. diphthericus*

6. *M. Septicus.*—Some deem it the cause of pyæmia.

7. *M. Bombycis.*—A destructive epidemic among silkworms of Southern France, but different from muscardine and gattine.

2*d Group. Microbacteria.*—Rodlike bacteria, resemble globular bacteria in the small size of cells and their temporary union into mucous masses, but are distinguished by their short cylindrical forms and spontaneous movements.

2*d Genus. Bacterium.*

1. *Bacterium Termo.*—Cells short, cylindrical, oblong. They turn on their axis and swim forward, then return a little or travel in curved lines as if trembling, or springing forward and then becoming quiet.

2. *B. Lineola.*—Cells cylindrical, broad, straight, with refractive soft contents, and fatlike granules. Single or in pairs.

3*d Group. Desmobacteria—Filamentous B.*—Filaments not constricted at the joints, but throughout cylindrical (leptothrix filaments). May form swarms but not zooglöa-form masses.

1*st Genus. Bacillus.*—Filaments straight.

1. *B. Subtilis.*—Butyric acid ferment.

2. *B. Anthracis.*—Bacteridia of gangrene of the spleen.

3. *B. Ulna.*

2*d Genus. Vibrio.*—Filaments wavy, thick, with single curve (*V. rugla*), or thin, with many curves (*V. serpens*).

4*th Group. Spirobacteria.*—Screw bacteria. Distinguished from vibrio by the closer regular permanent spiral of the filament.

1*st Genus. Spirochæta.*

1. *S. Plicatilis.*—In tartar from the teeth.

2*d Genus. Spirillum.*—Shorter and more distant spiral.

5*th Group.*

1*st Genus. Leptothrix.*

1 *L. Buccalis.*—Long, brittle, slender filaments, divided by partition-walls. Occurs on products of decomposition within the mouth; papillæ of tongue, tartar, etc. Also in the intestine, vagina, etc. It is thought by some to produce caries of the teeth.

2*d Genus. Sarcina.*

1. *S. Ventriculi.*—Four-fold flat cubical cells, generally with nuclei. Occurs in vomited fluid, urine, etc.

In addition to the above (provisional) arrangement, Wagner classifies vegetable parasites with respect to their pathological relations as follows:

I. MOULD DISEASES.

These are conditional upon the above-mentioned mould fungi. They occur chiefly upon parts affected with necrosis or other lesions, particularly ulcers of the skin and mucous membranes. On free surfaces they present an appearance resembling mould. Perhaps in this connection belongs the foot-fungus, or *Mycetoma Carterii*, which is endemic in India.

II. FUNGI OF TRUE PARASITIC DISEASES OF THE SKIN AND MUCOUS MEMBRANES.

1. *Trichophyton Tonsurans.*—This consists of round transparent spores, or spore-rows. They develop in the roots of the hair and pass into the shaft, so that the latter is destroyed and breaks off. It occurs also in the sheaths of the hair-roots and surrounding epidermis, seldom in the nails. It causes several diseases, especially of the scalp and beard, as *herpes tonsurans*, *porrigo scutellate*, *men-*

tagra (sycosis), *eczema marginatum*, etc. It is thought by some to proceed from aspergillus.

In examining hair, skin, etc., for fungi, the specimens should be soaked in liquor potassæ long enough to become transparent.

2. *Achorion Schönleinii—Favus Fungus.*—Mycelia composed of small, simple, or branching tubes divided by partitions. Spores round or oval, sometimes grouped in masses. The cause of *tinea favosa* of the scalp.

3. *Microsporon Audouinii.*—Undulating forked filaments on which spores are directly placed. Found round the shaft of the hair after its exit from the follicle, so thick that the hair breaks off and causes baldness. *Porrigo decalvans.*

4. *Microsporon Furfur.*—Masses of large, round, mostly nucleated spores, and long or branched cells. Sometimes with numerous broad filaments. Developed in the horny layer of the epidermis, commonly round the opening of hair follicles of the breast and back, producing yellowish discoloration and branlike scales, with itching,—*Pityriasis versicolor.*

5. *Oidium Albicans—Thrush Fungus*—Tubular filaments, branching stems, and minute spores. Ends of filaments lost in masses of spores, with a large, often divided spore-cell. Found in aphthæ of the mouth, tongue, throat, vagina, etc.

III. FUNGI AS EXCITORS OF FERMENTATION AND PUTREFACTION AND CAUSES OF DISEASE.

At page 137 the distinction between diseased conditions which invite fungi and the effects produced by fungi themselves was stated. That fungi are the cause of specific fermentations (acetic, alcoholic, lactic, butyric, etc.), is rendered very probable by modern researches, especially those of Pasteur. In decay, or oxidation, and in putre-

faction of organic bodies, fungi are important agents. In the former vibrios are found, and in the latter monads and bacteria. Decay is arrested if access of fungus germs is prevented. Putrefaction is as dependent on bacteria as the fermentation of non-nitrogenous bodies upon yeast-fungi.

Many acute infectious diseases are considered to proceed from fungi, although the reasons for such an opinion are chiefly theoretical, arising from the presence of fungi in those diseases. Such are diphtheria, pyæmia, puerperal fever, small-pox, etc. Many experiments have been made, by inoculation, etc., but thus far with little results. Observers differ greatly concerning the same disease, the specific fungus of one being disavowed by another. Still, much light may be expected respecting ætiology from observations of this kind.

II. Animal Parasites.

These inhabit either the external surface (epizoa) or internal organs (entozoa).

I. protozoa.

Gregarinidæ.—See page 180. *Gregarinidæ* are parasitic animals, generally regarded as the lowest of the protozoa, although this opinion is doubtful. They usually consist of a single cell, with an illy-defined membrane filled with granular and fatty sarcode, with nucleus and nucleolus. They are developed much like protophytes, page 140. The gregarina becomes motionless, globular, and encysted. The nucleus then disappears and the sarcode breaks up into little masses which become pointed at each end (pseudo-navicellæ). These masses escape as amœba, page 121, and develop new *gregarinæ*.

Globular psorospermiæ, as they are called, have been

found in the liver and intestines of rabbits and of man, and are regarded as the resting stage of *gregarinæ*.

INFUSORIA.—*Family, Heterotricha.*—Body covered with cilia, often in longitudinal rows. Stronger cilia about the mouth.

Balantidium Boli.—A common parasite in the rectum of hogs. Found sometimes in human intestine.

FLAGELLATÆ.—Infusorial organisms with lashlike cilia. —*Family, Monadina.* Round or oval. Transparent. A single or few whiplike hairs on anterior extremity.

Cercomonas.—With caudal filament and generally a single thin and long lash.

C. Intestinalis. — Found in the stools of cholera and typhoid fever, and on catarrhal mucous membrane of children.

C. Urinarius.—Urine of cholera and in alkaline albuminous urine.

C. Saltans.—On the dirty surface of ulcers.

Trichomonas.—With two or three short cilia near the anterior lash.

T. Vaginalis.—In the yellow acrid mucus of vaginal blennorrhœa.

II. VERMES (*Worms*).

1*st Class. Platodes—Platyelmia.*—Flat worms. Bodies flat, appendages, when present, of suckers and hooks. Generally hermaphrodite. Many without mouth or intestine, nourished by absorption.

1*st Order. Cestodes.*—Tapeworms. Long, articulated, flat, without mouth or alimentary canal. Prehensile organs anterior. The anterior part or head is small and somewhat globular. The neck is thinner. The joints lengthen and broaden in continuous succession until they reach their greatest circumference at the posterior extremity, where they may separate and live independently

as *proglottides*. The cellular connective parenchyma incloses in its periphery, especially on the head, small chalky concretions, in all parts the ramifications of a water-vascular system, and in the central parts the sexual organs. Each segment has its special male and female organs of generation.

Human tapeworms exhibit a complicated metamorphosis connected with alternate generation. Generally the ova with the proglottides pass from the intestines and are conveyed with food into the stomach of an animal. The embryos become free in the stomach, and by their movable hooklets bore their way into the bloodvessels and are deposited in various organs, as the liver, muscles, brain, etc. Here they become encapsulated and grow into larger vesicles, each of which is a cystworm. From its covering one (cysticercus) or several (echinococcus) nodular depressions grow into the interior, on the bottom of which is the armament of the tapeworm's head, in form of suckers and hooks. The transportation into the human stomach is effected by means of food, especially measled meat. The cyst is digested and the head of the tapeworm set free as a *Scolex*. This enters the small intestine, becomes fixed, and develops by gradual formation of segments the tapeworm body.

Family. Taniadæ.—Head pear-shaped or conoidal, with four round suckers. A rostellum or wreath of hooks between the suckers or anterior part of head. Proglottides distinctly separate and generally longer than broad.

A. Vesicular tapeworms, *Cysticæ*. Head rarely unarmed (T. mediocanellata), generally with rostellum and hooks. Middle stem of uterus gives off ramifying side-branches. Openings of sexual apparatus on the border, alternate on each side.

a. Vesicular tapeworms, whose heads are formed in the embryonal state.

1. *Tænia Solium.*—Single, or several together in small

intestine. Develops to from two to three meters long, and its proglottides ten mm. long and six mm. broad. Head the size of a pin, globular, with tolerably prominent suckers. Filamentous neck, almost an inch long The cystworm (*Cysticercus cellulosæ*) of this species has a preference for the muscles of the hog, but is found in other animals and in man.

2. *Tænia Mediocanellata.*—Larger than the T. solium. Head without a circle of hooks and rostellum, but with powerful suckers. The cystworm inhabits the muscles of cattle, but has not been found in man.

3. *T. Acanthotrias.*—The vesicle only is known. Found in muscles, subcutaneous tissue, and brain of man. Hook apparatus a triple circle of slender claws.

4. *T. Marginata.*—Mature tæniæ are like T. solium, but found in the dog and wolf. The larva abides in the omentum or liver of ruminants and swine, and sometimes of man. One extremity of the vesicle is drawn out in a necklike process, which contains the tapeworm.

b. Cyst tapeworms, whose heads bud from the embryonic capsules of the inner surface of the vesicle.

5. *Tænia echinococcus* consists of only three or four segments, the last of which exceeds in bulk all the others. It is three to four mm. long, and its thirty or forty hooklets are on a prominent rostellum. It lives in the intestine of the dog. The young state of this Tænia (*echinococcus*) is an almost motionless vesicle on the inner surface, of which numerous little heads bud in vesicles the size of a millet-seed. These are sometimes compound (daughter, granddaughter vesicles), inclosed one within the other. In this form they are found in man and cattle (especially in the liver). Other animals harbor generally single vesicles.

B. Common tapeworms, *Cystoideæ*. They represent no peculiar larvæ. Their larvæ occur only in cold-blooded animals or invertebrates. Thus the cysticercoid of *T.*

elliptica or *cucumerina* of the dog live in the lice which infest dogs, and the dogs are infected by eating these lice. Clinically, they are less important than cyst tapeworms. Head small and hook apparatus imperfect.

a. Head prominence with a single circle of small hooks.

6. *Tænia Nana.*—Small. Anteriorly filamentous, but larger near the middle. Once found in the duodenum of a boy.

7. *T. Flavo Punctata.*—33 cent. long. The anterior half of immature joints 0.2 to 0.5 mm. long and 1 mm. broad, which show behind the middle a large yellow spot. The receptaculum filled with sperm. Head unknown.

b. Papilla with multiple circle of hooks.

8. *T. Elliptica.*—Usually in dogs and cats.

Family Bothriocephalidæ.—Head flattened. Two deep fissure-like suckers. Articulations imperfectly marked.

9. *Bothriocephalus Latus.*—The largest human tapeworm. Sometimes 5 to 8 meters long and from 3000 to 4000 short and broad joints, seldom more than 3.5 mm. long, but 10 or 12 mm. broad. The last joints are nearly square. Anterior end threadlike. Proglottides pass away in lengths (from 2 to 4 feet). Ova oval, with transparent shells, and a lid at one end through which the embryo slips into the water. The six-hooked embryo is developed several months after the ova are passed.

10. *B. Cordatus.*—Smaller than *B. latus.* Head short and broad, heart-shaped.

2*d Order. Trematodes.*—Suckerworms. Parasitic solitary flat worms, with inarticulate leaf-shaped bodies; with mouth and bifurcated intestinal canal, without anus, with abdominal prehensile apparatus. Male and female organs mostly in the same individual. The distomata go through a complicated alternate generation and metamorphosis. The embryos escape from the ova into water and seek a new animal habitat, mostly snails. Here they develop into cyst-germs, which are the parents of the *Cercariæ*, which have a rudder-like tail and

move freely in the water. These enter a new aquatic animal, snail, worm, crab, or fish, pierce into the tissues and form a cyst. Thus the young, encysted, sexless distomata arise from the Cercariæ, the former received with the flesh of their supporters into the stomach, and thence freed from their cyst they enter other organs of another animal, where they become sexually mature.

Gen. Distomum.—Two suckers on the anterior part. Genital pores near the abdominal sucker.

a. Body broad and leaf-shaped.

11. *Distomum Hepaticum.*—Liver-fluke. The Cercariæ are probably encapsuled in fresh-water snails, and eaten by sheep infect them. The perfect *D. hepaticum* inhabits numerous herbivorous mammals and occurs in man.

b. Body more regular in form, without branched intestinal canal.

12. *D. crassum.*

13. *D. Lanceolatum.*—Both extremities pointed. Associated with *D. hepaticum* in the bile-ducts.

14. *D. Ophthalmobium.*—Once found in the crystalline lens.

15. *D. heterophyes.*

c. With separate sexual apparatus. Body long and slender. Female almost cylindrical.

16. *D. Hæmatobium.*—Oral and abdominal suckers equal in size. Color white. Is frequent in Egypt, in the veins as well as intestinal canal and bladder. Feeds on the blood.

Gen. Monostomum.—Has no abdominal sucker.

17. *Monostomum Cutis.*—Found once in the lens.

2d Class. Nematelmia.—Roundworms. Bodies rounded, pouched, or filamentous, without rings or segments. Sometimes with papillæ or hooks on anterior pole Sexes distinct.

1st Order. Acanthocephali—Vertex bearing hooks. No mouth or intestine.

18. *Echinorrhynchus.*—Inhabits the intestine of several vertebrates. One found in a leucæmic child.

2*d Order. Nematodes.*—Threadworms. Bodies round, threadlike, with mouth and intestine. Armament, when present, of papillæ or spikelets and hooks within the mouth. Development by single metamorphosis, yet many young forms have an abode altogether different from that of their parents, and often the young and sexually mature inhabit different organs or different animals. Some live parasitically in plants.

1*st Sub-order. Strongyloidæ.*—Nematodes with anus.

1*st Family. Ascarides.*—Mouth with three lips or papillæ. Sometimes teeth in the throat. Most lay hard-shelled eggs.

19. *Ascaris Lumbricoides.*—Roundworm. Cylindrical body. Male 250 mm. by 3 mm. Female 400 mm. by 5.5 mm. Tail of male conical and hooked.

20. *A. Mystax.*—Smaller than the preceding. Identical with the common roundworm of cats.

21. *Oxyuris Vermicularis.*—Threadworm. Body filamentous, white. Three lips on the head. Inhabit chiefly the rectum and large intestine, but may wander to vagina.

2*d Family. Strongyloidæ.*—Mouth generally armed with a horny surface or hooks.

22. *Strongylus Gigas.*—Long red worm. Viviparous. In the pelvis of the human kidney.

23. *S. Longevaginatus.*—Filamentous, white.

24. *S. Armatus.*—Cause of the so-called colic of the horse, which is really aneurism of the intestinal arteries.

25. *S. Duodenalis.*—Body cylindrical. Mouth wide, with two claw-shaped hooks. In Italy and Egypt found in the intestines by thousands. Gives rise to anæmia, etc.

3*d Family. Trichotrachelidæ.*—Moderately large, longitudinally striated worms.

26. *Trichocephalus Dispar.*—Long threadworm. Body short, 2 cent. long by 1 mm. thick, with filiform neck,

20 to 25 mm. long, and head; in the male spiral, in the female straight. Generally found in the colon of children or adults.

27. *Trichina Spiralis.*—On the second day after eating raw flesh containing trichinæ, and after digestion of the inclosing capsule, the worm is sexually mature Copulation occurs, and on the sixth day after the females bring forth each about 1000 filamentous embryos. These pierce the intestinal wall and wander through the tissues to the voluntary muscles, where they coil up spirally and become encysted. The cysts may become hard and even calcify. In this state they may remain for years capable of development. The hog is considered the original bearer of trichinæ, whence they have infected other animals.

4. *Family. Filaridæ.*—Long filamentous body.

28. *Filaria Medicensis.*—Threadworm. Guineaworm. Inhabits the subcutaneous tissue of the foot. Found only in tropical countries.

3*d Class. Annelidæ.*—Ringed worms. Cylindrical or flattened. Segmented body with brain, œsophageal ring, chain of abdominal ganglia and bloodvessels.

Order Hirudinis.—Leech. Body with narrow rings and terminal disk. No feet. Hermaphrodite.

Sub-order Gnathobdellæ.—Gill-leach. Throat with three often dentated gills. A sort of oval sucker disk in front of the mouth. Blood mostly red.

29. *Hirudo Medicinalis.*—80 to 90 fine teeth on the free border of the gills. Is three years in arriving to sexual maturity.

III. ARTHROPODA.

Animals laterally symmetrical. Bodies segmented. Limbs articulate. Brain and abdominal ganglia present. Propagation generally sexual.

Class Arachnidæ.—Air-breathing. Head and thorax blended. No feelers. Two pairs of jaws and legs. Abdomen without members. Sexes distinct.

Order Linguatulidæ (Pentastomidæ).—Worm-shaped, ringed. Mouth rounded, with horny border. Four legs, hooklike and sheathed. Surface hard and pierced by stigmata. Metamorphosis complete.

30. *Pentastomum Tænioides.*—Inhabits the nasal cavities of the dog and wolf. The larva have been found in man.

31. *Pentastomum Denticulatum.*—Encapsuled, curved, calcified. On the surface of the liver, etc.

Order Acarinæ.—Mites. Body compact, inarticulate. Mouth for biting, sucking, or stinging. Respiration by tracheæ.

Family Dermatophili.—Hair-follicle mite. Elongated. Worm-shaped, fringed abdomen. Suckers and stiletto-shaped jaws. Four pairs of short bipartite feet.

32. *Acarus Folliculorum* (Dermodex Folliculorum).—Found often in ear-wax and sebaceous glands of face.

Family Acaridæ.—Mites. Microscopic, soft-skinned. Legs short, with disks for prehension.

33. *Acarus, or Sarcoptes Scabiei.*—Itch-mite. Body round, arched, with transverse striæ covered with spines and bristles. Young have but one pair of feet.

Family Ixodæ.—Ticks. Larger, blood-sucking mites, with firm back-shield and dentated mandibles. Live on plants, and occasionally on man. The female inserts its proboscis, and fills itself with blood, causing pain and suppuration. There are several species.

Family Trombididæ.—Running mites. Body brightly colored, covered with hair. They live on plants, etc., but sometimes on man. The *Leptus autumnalis*, gooseberry or harvest mite, is often troublesome in summer.

Class Hexapoda.—Insects.

Order Rhynchota.

Sub-order Aptera.—Wingless insects, with short, turned-

in, fleshy beak, and piercing bristles, or with rudimentary biting mouth. Body has usually nine articulations.

Pediculus Capitis.—Head-louse.

P. Pubis or Phthirius Inguinalis.—Crabs.

P. Vestimenti.—Clothes-louse.

Sub-order Hemiptera.

Cimex Lectularius.—Bed-bugs.

Order Diptera.—Insects with mouths for piercing or sucking. Inarticulate thorax, with cuticular anterior wings. Swing-bats for posterior wings. Complete metamorphosis.

Pulex Irritans.—Flea.

Pulex or Dermatophilus Penetrans.—Sand-flea. Native of South America. Breeds under the cutis, and the ova develop in the sand.

Œstrus Hominis.—Gad-fly. May deposit ova in skin of man, producing boils.

Musca Vomitoria.—Large, blue-bottle fly.

M. Sarcophaga.—Common flesh-fly.

M. Domestica.—House-fly.

All may deposit ova or fully formed larva in cavities and wounds.

V. DISEASE-GERMS.

The germ-theory of disease ascribes disease, particularly infectious disease, to the introduction of minute parasitic organisms into the tissues of the body, and their subsequent multiplication there. Many of the early naturalists entertained substantially this view, as Vallisneri, Réaumur, and Linnæus. It was considered, however, but a mere hypothesis, until recent microscopic observations have revived an interest in this direction. Liebermeister, in his recent monograph on typhoid fever, says, "Within the last ten years a great revolution has taken place with regard to the popular signification of a *contagium vivum*. New investigations on the appearance, mode of propaga-

tion, and the significance of the low organisms, new facts in regard to the extension of national diseases, and also a number of quite positive discoveries by numerous investigators, have removed the old opposition to the theory, or even been the means of furnishing definite proof of its correctness." This quotation expresses the most sanguine views of the adherents of this theory.

We have already referred to the connection of mould and yeast fungi with the process of fermentation, and it is quite possible that the introduction of such germs into the body may produce slight irritations and even inflammations from the increase and multiplication of the fungi, and the chemical changes induced by them. We have also seen that fungi are causes of putrefaction as well as of fermentation in organic bodies. Yet the diseases of the human body, in which fungi have been proved to be real causes, are but few. Among vegetable diseases caused by fungi are the rust, smut, etc., of our grains, the "vine disease," "potato disease," etc. Among animal diseases of this kind are some affections of caterpillars, flies, etc., and gangrene of the spleen in mammals. In splenic gangrene, however, as well as in mycosis intestinalis, pyæmia, diphtheria, etc., in which fungi occur, the bacteria may be merely the carriers of the disease, or may develop because of special pabulum furnished by the diseased structure which is not present in the normal state.

Another theory of disease-germs has been published by Dr. Beale, which regards them as minute masses of depraved bioplasm, originated probably in man's own body, or in the bodies of some of the animals domesticated by man.

Both theories may be true in reference to the cases to which they are applicable. They do not even necessarily exclude each other. Each kind of disease-germ, bioplastic or fungoid, may have a range of action peculiarly its own.

Dr. Beale's views seem to apply to a much wider field

of research than the other, and are therefore given here in abridged form.

Dr. Beale objects to calling disease-germs parasites, since parasites are organisms themselves, and not mere particles of living matter. He freely admits the great variety and rapid growth of microscopic fungi and algæ, and the readiness with which they may enter and traverse the textures of the body, but considers them to be but seldom the cause of disease. He says, "In every part of the body of man and the higher animals, and probably from the earliest age, and in all states of health, vegetable germs do exist. These germs are in a dormant or quiescent state, but may become active and undergo development during life should the conditions favorable to their increase be manifested. There is not a tissue in which these germs do not exist, nor is the blood of man free from them. They are found not only in the interstices of tissues but they invade the elementary parts themselves. Multitudes infest the old epithelial cells of many of the internal surfaces, and grow and flourish in the very substance of the formed material of the cell itself. In many very different forms of disease these germs of bacteria, and probably of many fungi, are to be discovered in the fluids of the body, but the evidence yet adduced does not establish any connection between the germs and the morbid process. The diseases known to depend upon the growth and development of vegetable organisms are local affections, and the structure of the organism can be made out without difficulty, but contagions are general affections, and no such success attends our efforts to prove that vegetable organisms are the active agents. In fact, the fungi which commonly grow on the surface and in other parts of the body do not produce disease. The germs of fungi may remain perfectly passive in healthy textures, growing and multiplying only in those which have already deteriorated in consequence of disease or old age."

We have already considered Dr. Beale's views respecting bioplasm—page 118—as the forming material of the tissues. At page 246 we have also referred to his doctrine of inflammation, etc. These views will prepare us to understand the theory of "disease-germs," considered as degraded particles of bioplasm. "Degradation in power is commonly associated with increased rate of growth, and with remarkable vitality. The actively living degraded bioplasm may retain its vitality although removed from the living body, and it may grow and at length destroy other living organisms to which it gains access." Animal fluids and secretions, normal as well as those known to have contagious properties, contain minute particles of bioplasm, which are sometimes so small as to require the highest microscopic powers to render them visible, yet they are capable of growth and multiplication to a vast extent, so that a minute particle of vaccine or other lymph may originate important changes in a large number of persons.

The virulent poison of dissection-wounds cannot be ascribed to vegetable germs, since it is most virulent shortly after death of the subject of dissection, and when putrefactive decomposition has taken place, and bacteria swarm, the real contagious virus is dead. Such is the vitality, however, of some forms of degraded bioplasm, that they will not only multiply on mucous surfaces, but live long after their removal, as in purulent ophthalmia, gonorrhœal pus, etc., so that they may be transported in various ways from one place to another and still retain their multiplying power. A very small portion of blood, serum, or of the tissues of an affected animal is sufficient to propagate cattle-plague. Even the breath of the diseased organism contains numerous virulent particles. There is reason, also, for thinking that a single epithelial cell may contain multitudes of active particles in the case of syphilitic poison which may remain dormant, perhaps for years,

or may from time to time give rise to changes peculiar to it. Particles of living tubercle may be so minute as to be carried in the atmosphere, although tubercle is not eminently contagious. As to cancer germs, many circumstances render it improbable that they can be transmitted, so that living disease germs differ remarkably in vital power as well as forms of activity. Yet they resemble each other in general appearance. Neither by its form, chemical composition, or other demonstrable properties, can the vaccine germ be distinguished from the small-pox germ, or the pus germ from either. All are like the minute particles of bioplasm of the blood, from which they differ so remarkably in power. Of the conditions under which these germs are produced, and of the manner in which the rapidly multiplying matter acquires its new and marvellous specific powers, we have very much yet to learn. For the manner of detecting these germs in the air, etc., see the former part of the present chapter. Mr. Lister's excellent plan for the antiseptic treatment of wounds, and especially the results of carbolic acid spray in surgical operations, together with many positive experiments, show that carbolic acid has a powerful action in arresting vital phenomena or destroying bioplasm. In its presence embryonic life is impossible; under its powerful influence all minute forms of life perish. Dr. Beale, also, refers to the effects of carbolic acid, and sulpho-carbolates administered internally, in checking the too rapid growth of bioplasm in the blood and tissues, as well as to the importance of disinfectants, or the destruction of disease germs in the air, sewage, etc.

Among the strongest objections to the theory of fungoid disease germs are those given by Dr. Bastian (a strong supporter of spontaneous generation), that the theory demands a belief in the existence of organisms never known in their mature state, and whose existence is not demonstrated but merely presumed; that such germs have been

experimentally shown to be incapable of producing the diseases they are assumed to cause; and that feeding on putrid flesh, swarming with bacteria, as the Kalmucks do habitually, produces no injurious consequences. These objections do not apply to the theory of disease germs advanced by Dr. Beale, while it will be found to accord with the most careful and thorough investigations in biology and pathology. Yet Beale's views have received less attention than they deserve, perhaps because of his pronounced antagonism to the evolutional philosophy, which is so commonly taught under the guise of natural science.

APPENDIX.

RECENT ADDITIONS TO THE MICROSCOPE AND MICROSCOPIC TECHNOLOGY.

OPTICIANS and microscopists strive continually after absolute perfection in their instrumental means of research, so that every little while some new piece of apparatus or new method is announced. The most important recent additions are named here.

IMPROVEMENTS IN MECHANISM.

Some notable improvements have been added to first-class instruments. Zentmayer's "Centennial" model has a peculiarly swinging mirror and sub-stage. The mirror-bar is pivoted in the plane of the object on the stage, so that illuminating appliances in the sub-stage may be effected at every angle of inclination, and may even be brought above the stage as a condenser for opaque objects. Mr. Bullock, of Chicago, has also adopted a similar plan in his first-class instruments, and the Bausch & Lomb Optical Company, of Rochester, New York, place a swinging-bar below the glass stage of their "Professional" stand, which instrument has many excellent qualities, although it does not reach the idea proposed by Zentmayer.

The latter optician has also adopted this mechanism in a cheaper form for students in his "Histological Microscope." The "Physician's Microscopes," of the Bausch & Lomb Company, are also models of cheapness and excellence. Beck's "National" microscopes are among the best educational stands.

IMPROVEMENTS IN OBJECTIVES.

A laudable desire to place really good objectives in the hands of students at a reasonable price has led to great emulation among opticians. Spencer, Tolles, Wales, Gundlach, and the Bausch & Lomb Company, in addition to their most perfect objectives, both dry and immersion, which must necessarily demand a high price, have prepared others at less cost for professional and students' use, which are worthy of all praise. Some of them fall but little below the performance of the very best glasses.

Test-objects, such as those referred to at page 56, and which formerly required objectives of best workmanship and highest power, are now resolved by a large number of objectives. The $\frac{1}{4}$-inch of Spencer or Tolles, the $\frac{1}{8}$th of Gundlach, and even a $\frac{1}{10}$th of Bausch & Lomb, with proper eye-pieces and illumination, will exhibit nearly all which can be desired, yet powers of from $\frac{1}{8}$th to $\frac{1}{16}$th are still better. For refined histological work $\frac{1}{25}$th or $\frac{1}{50}$th, or even $\frac{1}{75}$th inch (Tolles), will be found most useful.

The desire to obtain the largest angle of aperture possible has, however, led to a reduction of the working distance, or the distance between the object and front of the objective, so that only the thinnest covers can be used.

For immersion objectives, also, a variety of fluid media have been proposed, as glycerin, castor oil, oil of cedar, and kerosene.

IMPROVEMENTS IN EYE-PIECES AND AMPLIFIERS.

Periscopic eye-pieces, consisting of a plano or double convex field lens and an achromatic meniscus, have been brought to great perfection by E. Gundlach and the Bausch & Lomb Company. Solid eye-pieces by Tolles have also found favor. I have made some improvement in field of view and definition by substituting a meniscus for the

field-glass of the periscopic eye-piece. The amplifier referred to at page 26, or an achromatic concave meniscus, is added to this form of eye-piece about three inches from the field-glass. I find this to give better definition than the amplifiers of Zentmayer and Tolles, which are placed at the end of the draw-tube.

IMPROVEMENTS IN ILLUMINATORS.

Most of the improvements suggested in illuminators have been connected with oblique light. In Amici's prism, Nachet's prism, Reade's condenser, etc., the purpose is to utilize oblique light and exclude central. In the illuminator proposed at page 35 I have combined a condenser with an illuminating prism. Mr. Edmunds (after Mr. Wenham) has contrived a paraboloid lens with the front cut off flat and polished. This is in fluid contact with the under side of the slide. Mr. Wenham's reflex condenser, although difficult to use, is capable of excellent effects. A small lens (plano-convex) placed in immersion contact with the under side of the slide is also used. Dr. Woodward's prism, however, for effectiveness and cheapness, bids fair to surpass them all. This is a small right-angled prism, with its base in immersion contact with the slide, receiving the light from the mirror or condenser at right angles to the facet.

The hemispherical condenser and oblique illuminator of Mr. Gundlach, attached to the "Professional" microscope of the Bausch & Lomb Company, are also well adapted for the purpose.

DOUBLE-STAINED PREPARATIONS.

Sections of vegetable tissues present a beautiful appearance under the microscope when doubly stained. They should first be soaked in alcohol, if green, to deprive them of chlorophyll, then subjected to a solution of chloride of

lime (¼ ounce to 1 pint of water) until thoroughly bleached. Soak then in a solution of hyposulphite of soda (1 drachm to 4 ounces water) for an hour, and after thoroughly washing in several changes of water transfer them to alcohol. Prepare some red staining fluid by dissolving ½ a grain of magenta crystals in 1 ounce of alcohol. Soak the specimen in this for thirty minutes, then rapidly rinse it in alcohol and place in a blue fluid made by dissolving ½ grain of anilin blue in 1 drachm of distilled water, adding 10 minims of dilute nitric acid and alcohol enough to make 2 ounces. Let the specimen remain only two or three minutes in this, rapidly rinse in alcohol, put in oil of cajeput, thence into turpentine, and mount in balsam. The principle of double staining depends on the affinity which certain dyes have for certain cells. Thus, if sections stained in red or green anilin be soaked in alcohol, and those stained by logwood in alum-water, the color will leave the loose parenchyma and be retained by the denser cells, while specimens stained in blue anilin if left in alcohol, and those stained in carmine if left in water, lose color more slowly in the parenchyma than in other parts.

Eosin-staining.—Dilute solutions of eosin, an anilin preparation, 1 part to 1000 of water, has been proposed for animal tissues, since the different parts are differentiated by different tints. Sections are stained in a minute to a minute and a half, then washed in water acidulated slightly with acetic acid, and examined in glycerin; or they can be mounted in balsam after the water is removed (see page 80).

CLASSIFICATION OF CRYPTOGAMIA.

In addition to the classification given in previous chapters, the following, chiefly compiled from the *Micrographic Dictionary*, may be useful:

Ferns.

Order 1. POLYPODIACEÆ.—Sporanges on lower surface in groups, but never blended. Annulus present, but variable.

Family I. Polypodiodideæ.—Numerous sporanges in sessile sori, divided equally by a vertical annulus.

A. No indusium.

Tribe 1. *Polypodieæ.*—Sori at apices of veins.

* Veins pinnate.

† Margins of fertile fronds not revolute.

Gen. 1. *Polypodium.*—Sori globose on apex or back of veins or venules.

Gen. 2. *Marginaria.*—Sori globose immersed deeply in backs of veins or venules.

Gen. 3. *Pleopeltis.*—Sori globose on backs of veins or venules, with peltate paraphyses concealing the sporanges.

† † Margin of fertile fronds revolute.

Gen. 4. *Struthiopteris.*—Sori globose on backs of veins or venules.

* * Veins anastomosing. No free veins in the areolæ.

Gen. 5. *Dictyopteris.*—Sori globose on anastomosing venules. Venules anastomosing in irregular hexagonal spots.

* * * Veins anastomosing. Free veins in areolæ.

Gen. 6. *Niphobolus.*—Sori globose on apex of venules. Venules branched, forming transverse rhomboid spots.

Tribe 2. *Acrosticheæ.*—Sporangia scattered over the whole surface.

Gen. 1. *Acrostichum.*—Sori on all the veins and parenchyma. Veins branched and anastomosing.

Gen. 2. *Campium.*—Veins branched, with free venules.

Gen. 3. *Polybotrya.*—Veins pinnate, scarcely anastomosing.

Tribe 3. *Tænitideæ.*—Sori linear, extending to the areolæ of the leaves.

Gen. 1. *Pleurogramma.* Sori contiguous on each side of the rib, parallel, linear, and continuous. Veins simple.

Gen. 2. *Tænitis.*—Sori submarginal in middle of disk of leaf, linear, elongated, and continuous. Veins anastomosing into meshes.

Gen. 3. *Notholæna.*—Sori marginal, linear, continuous. Veins pinnate.

Tribe 4. *Grammitideæ.*—Sori linear, confined to the veins or veinlets.

Gen. 1. *Grammitis.*—Sori linear or roundish, seated on certain arms of the veins. Veins simple or forked, scarcely anastomosing.

Gen. 2. *Sellignæa.*—Sori linear or roundish, on certain arms of veins. Veins much branched and anastomosing without free veins.

Gen. 3. *Synamnia.*—Sori oblong, on back of lowest venule. Veins branched, anastomosing, with free venules.

Gen. 4. *Meniscium.*—Sori reniform, on back of transverse venules. Veins pinnate, anastomosing.

Gen. 5. *Antrophyum.*—Sori imbedded on the back of all the veins and venules. Veins branched, anastomosing.

Gen. 6. *Hemionitis.*—Sori on back of veins. Veins branched, anastomosing in regular meshes.

Gen. 7. *Gymnogramma.*—Sori on back of veins. Veins pinnate or forked, scarcely anastomosing.

Tribe 5. *Vittarieæ.*—Sori in the grooved margin, which simulates an indusium.

Gen. 1. *Vittaria.*—Sori solitary. Fronds ribbonlike or grassy.

B. With an indusium.

Tribe 6. *Adianteæ.*—Sori linear, marginal, at apices of veins. Indusium spurious, formed by revolute margin.

* Sori on the notches of the fronds.

Gen. 1. *Lonchitis.*—Veins anastomosing. Sori linear, semilunate. Indusium marginal, semilunar.

Gen. 2. *Hypolepis.*—Veins primate. Sori sub-globose, on inferior border of teeth of frond. Indusium marginal, semilunar.

* * Sori on margin of the frond.

Gen. 3. *Lomaria.*—Veins primate, forked; fertile fronds narrower. Sorus linear, continuous.

Gen. 4. *Pteris.*—Veins primate. Sorus continuous.

Gen. 5. *Amphiblestra.*—Primary veins strong. Venules anastomosing in hexagonal spots. Sorus linear.

Gen. 6. *Litobrochia.*—Veins anastomosing hexagonally. Sorus linear.

Gen. 7. *Allosorus.*—Veins primate. Sori at first roundish, then confluent and linear, covered by the reflected margin.

Gen. 8. *Cassebeera.*—Veins primate. Sori two under each notched tooth of the leaf.

Gen. 9. *Adiantum.*—Veins fan-primate. Sori linear or semilunar, free within.

Gen. 10. *Hewardia.*—Veins reticulated. Sori linear. Indusium linear or semilunar.

Gen. 11. *Cheilanthes.*—Veins primate. Sori sub-globose, minute, covered by reflexed apex of tooth and the indusium.

Tribe 7. *Dicksonieæ.*—Sori globose, apical. Indusium lateral, two-valved.

Gen. 1. *Dicksonia.*—Valves of indusium unequal.

Gen. 2. *Cibotium.*—Valves nearly equal.

Gen. 3. *Cystodium.*—True indusium plane, false one hoodlike.

Gen. 4. *Thrysopteris.*—Sori semiglobose. Indusium cup-like. Sori on a thryse (leaf without parenchyma).

Gen. 5. *Deparia.*—Sori as in 4. Parenchyma of leaf developed.

Tribe 8. *Davallieæ.*—Sori apical, inframarginal. Indusium one-valved.

Gen. 1. *Davallia.*—Sori globose. Indusium cup-shaped, the mouth truncated. Veins primate.

Gen. 2. *Lindsæa.*—Sorus linear, continuous. Indusium parallel with leaf margin, free outside. Veins dichotomous.

Gen. 3. *Dictyoxyphium.*—Sorus and indusium as in 2. Veins anastomosing with free venules.

Gen. 4. *Schizoloma.*—Sorus and indusium as in 2. Veins anastomosing in hexagonoid meshes.

Tribe 9. *Asplenieæ.*—Sori on veins. Indusium persistent, lateral, the margin free.

Gen. 1. *Scolopendrium.*—Veins primate. Sori linear, in pairs on adjacent sides of two parallel veinlets.

Gen. 2. *Antigramma.*—Veins primate, veinlets anastomosing. Sori linear, in pairs facing together.

Gen. 3. *Camptosorus.*—Veins as 2. Sori elongated, diverging.

Gen. 4. *Diplazium.*—Veins primate, veinlets free. Sori linear, in pairs back to back.

Gen. 5. *Oxygonium.*—Veins primate, veinlets anastomosing at the ends. Sori as 4.

Gen. 6. *Asplenium.*—Veinlets free. Sori linear, single on back of vein or veinlet.

Gen. 7. *Ceterach.*—Indusium replaced by scales. Sori linear on back of veins.

Gen. 8. *Neottopteris.*—Veinlets anastomosing at ends. Sori linear, single.

Gen. 9. *Athyrium.*—Veins primate. Sori straight, curved, or reniform, but attached by a linear edge.

Gen. 10. *Blechnum.*—Sori marginal, somewhat confluent. Indusium opening inwards.

Gen. 11. *Doodia.*—Veins parallel, anastomosing slightly. Sori lunate or linear, in one or two rows parallel with midrib. Indusium flat.

Gen. 12. *Woodwardia.*—Veinlets form hexagonal meshes. Sori lunate or linear, parallel with midrib in one row. Indusium convex, immersed.

Gen. 13. *Cystopteus.*—Indusium suborbicular, fixed by a lateral inferior point.

Gen. 14. *Onoclea.*—Fertile pinnæ contracted into globules. Indusium lunate, attached on a short horizontal veinlet.

Tribe 10. *Aspidieæ.*—Sori subglobose. Indusium with central or eccentric point of attachment, free all round.

Gen. 1. *Lastræa.*—Indusium reniform. Veinlets free at ends.

Gen. 2. *Nephrolepis.*—Indusium reniform. Sori on tips of upper veinlets. Petioles articulated with the rachis.

Gen. 3. *Nephrodium.*—Indusium reniform, veinlets inosculating.

Gen. 4. *Aspidium.*—Indusium orbicular, peltate. Veins branched, anastomosing hexagonally, with free veinlets.

Gen. 5. *Polystichum.*—Indusium orbicular, peltate. Sori on middle of veins below the bifurcations.

Gen. 6. *Sagenia.*—Indusium orbicular, peltate. Veinlets anastomosing hexagonally without free ringlets.

Gen. 7. *Fadyenia.*—Indusium cordate. Sori apical, biseriate. Veinlets reticulate.

Gen. 8. *Didymochlæna.*—Indusium oblong-elliptic, fixed in the middle by a longitudinal crest.

Gen. 9. *Matonia.*—Indusium orbiculate, peltate, umbonate, the margins deflexed, covering about six sporanges.

Tribe II. *Pecopteæ.*—Indusium inferior, ultimately lobed or ciliated.

Gen. 1. *Paranema.*—Sori pedunculate. Indusium cup-shaped, splitting into 2–4 lobes. Sporanges on punctiform receptacle. Veins pinnate.

Gen. 2. *Dicnemon.*—Sori regular. Indusium sessile, spherical, at first closed. Sori on a punctiform receptacle, then bursting irregularly at the summit.

Gen. 3. *Woodsia.*—Sporanges pedicellate, inserted at bottom of indusium which is cup-shaped and hairy at margin. Veins pinnate.

Gen. 4. *Hypolepis.*—Sporanges on almost obsolete axis. Indusium cup-shaped, fringed at margin. Veins anastomosing.

Family II. CYATHEEÆ.—Numerous sporanges, united in sori on a salient axis, with a somewhat oblique annulus.

A. Sori without indusia.

Gen. 1. *Alsophila.*—Sori globose, regularly arranged. Sporanges on globose axis and imbricated.

Gen. 2. *Trichopteris.*—Sori globose, regularly arranged, laterally confluent. Sporanges on globose axis, areolate and crinite with long hairs.

Gen. 3. *Metaxya.*—Sori globose, each fertile vein bearing several, irregularly scattered. Sporangia on globose axis, beset with long articulated hairs.

B. Sori indusiate.

Gen. 4. *Hemitelia.*—Sori globose, each solitary on a pinnule. Indusium an ovate, concave, torn scale, at lower side of the base.

Gen. 5. *Cnemidaria.*—Sori globose, regularly arranged. Indusium forming an involucre, at length irregularly torn or partite.

Gen. 6. *Cyathea.*—Sori hemispherical, regular. Indusium first closed, then bursting and cup-shaped.

Gen. 7. *Schizocœna.*—Sori regular. Indusium of six lobes surrounding the globose receptacle.

Family III. GLEICHENIEÆ.—Sporanges united in fours into sori, and surrounded by an oblique annulus, like a turban.

Gen. 1. *Gleichemia.*—Sporangia in roundish sori. Indusium absent. Leaves forking.

Gen. 2. *Platyzoma.*—Sporanges in pointlike sori. Indusium spurious, formed by revolute margin of leaf, leaves undivided.

Family IV. PARKERIEÆ.—Sporanges ununited into sori, and divided equally by a vertical annulus.

Gen. 1. *Ceratopteris.*—Sporanges surrounded by a broad, complete, articulated annulus, placed on longitudinal veins. Spores globose, trifariously streaked.

Gen. 2. *Parkeria.*—Sporanges with almost obsolete basilar annulus, or longitudinal veins. Spores three-sided, concentrically streaked.

Family V. OSMUNDEÆ.—Sporanges united in sori, and covered on the back by a broad and imperfect annulus.

Gen. 1. *Osmunda.*—Sporangia on metamorphosed pinnules.

Gen. 2. *Todea.*—Sporangia on unchanged pinnules.

Family VI. SCHIZÆEÆ.—Sporanges united in sori, and annulus like a skull-cap with radiating streaks.

Gen. 1. *Aneimia.*—Sporangia twin, sessile in two rows, on lateral lobes of leaf, contracted into a panniculate immarginate rachis, naked, splitting longitudinally outside. No indusium.

Gen. 2. *Schizœa.*—Sporanges sessile in two or four rows in linear membranous-margined lobes, pectinately oppo-

site or digitate at apex of leaf, set among hairs, splitting longitudinally on the outside. No indusium.

Gen. 3. *Lygodium.*—Sporangia sessile, alternately biseriate on marginal lobes of leaf, splitting longitudinally, each veiled by a scalelike, hood-shaped indusium adhering transversely to the nerves.

Gen. 4. *Mohria.*—Sporangia sessile in one row, close to margin of leaf, splitting longitudinally on the outside. A spurious indusium formed by revolute margin of leaf.

Order 2. MARATTIACEÆ.—Sporanges on lower surface, usually blended together, or very closely approximated. No annulus.

Gen. 1. *Angiopetris.*—Sporangia in two rows near apex of transverse veins, distinct, forming linear sori, opening by a slit on outer side. No indusium.

Gen. 2. *Kaulfussia.*—Sporangia on anastomoses of veins, radiately connate, forming roundish sori, opening by a slit at apex.

Gen. 3. *Marattia.*—Sporangia in two rows near apex of transverse veins, connate, forming oblong sori, gaping transversely by a vertical slit. Indusia connate with sori.

Gen. 4. *Eupotium.*—Sporangia as 3, but pedicellate.

Gen. 5. *Danæa.*—Sporangia in two rows, near transverse veins, connate into linear sori, opening by a pore. Indusia superficial, encircling the sori.

Order 3. OPHIOGLOSSEÆ.—Sporanges on lower surface of leaf (reduced to mere ribs), never blended. No annulus.

Gen. 1. *Ophioglossum.*—Sporanges dehiscing transversely, connate on an undivided distichous spike.

Gen. 2. *Botrychium.*—Sporanges as last, on a distichous, secund, bi-tri-pinnate spike.

Gen. 3. *Helminthostachys.*—Sporanges dehiscing exter-

nally, vertically, from base to middle, collected in whorls, with crestlike appendages, and stalked, arranged distichously on an elongated spike.

Order 4. HYMENOPHYLLEÆ.—Sporanges attached to a common stalk, prolonged from end of vein of leaf, and contained in a kind of cup formed by a lobe of leaf above and indusial lobe from lower surface of leaf. Obliquely transverse annulus.

Gen. 1. *Trichomanes.*—Sporanges sessile around base of an exserted filiform column projecting from margin of leaf, surrounded by a cup shaped indusium continuous with leaf.

Gen. 2. *Hymenophyllum.*—Sporanges sessile up to summit of a column projecting from the margin of the leaf, sub-elevated, but not exserted beyond the indusium, which is two-valved.

Gen. 3. *Loxsoma.*—Sporanges stalked, inserted up to summit of a sub-elevated exserted column in margin of leaf, surrounded by an indusium, with truncated mouth, entire.

MICROSCOPIC FUNGI.

Order CONIOMYCETES.—The mycelium may be short filaments converted into spores, or a flocculent patch in decaying matter or under the epiderm of plants, or more completely organized into hollow conceptacles containing spore-bearing filaments.

Family I. SPHÆRONEMEI.—Conceptacles rising from microscopic mycelia growing beneath the epidermis of leaves, stems, etc., containing a chamber lined by a perithecium bearing single, often septate spores, and bursting by a pore at the summit.

Gen. 1. *Coniothyrium.*—Conceptacle free, membranous, opening by an irregular pore at the summit. Spores globular.

2. *Leptostroma.*—Conceptacle innate, subumbonate in the centre, dimidiate, at length falling off, leaving a thin disk.

3. *Phoma.*—Conceptacle ostiolate, very thin, innate, immersed, rounded, with a simple pore. Spores oblong, simple.

4. *Leptothyrium.*—Conceptacle operculate, innate, shield-shaped, not radiate-fibrous. Spores spindle-shaped, simple.

5. *Actinothyrium* —Conceptacle operculate, innate, etc., as 4.

6. *Microthecium.*—Conceptacle indehiscent, membranous, immersed, endophytic. Spores simple.

7. *Cryptosporium.*—Conceptacle membranous, opening irregularly at summit. Spores spindle-shaped, simple.

8. *Sphæronema.*—Conceptacle horny, innate-superficial, produced into a neck, ostiole simple. Spores oblong, simple.

9. *Acrospermum.*—Conceptacle leathery externally, fleshy within, elongate-clavate, ostiole simple. Spores stick-shaped, simple.

10. *Diplodia.*—Conceptacle horny, innate-superficial or immersed, perforated by a pore or irregularly opened or ostiolate, ostiole more or less produced. Spores ovoid or ellipsoid, double, then halved into compressed-ternate semi-ellipsoid sporules.

11. *Hendersonia.*—Conceptacle fleshy, innate superficially or immersed, perforated by a pore, opening irregularly or ostiolate, ostiole produced. Spores globose, cylindrical or discoid.

12. *Septoria.*—Conceptacle horny, innate-immersed, rounded, ostiole simple. Spores cylindrical, septate.

13. *Vermicularia.*—Conceptacle bristly, depressed, bursting irregularly. Spores minute, linear.

14. *Neottiospora.*—Conceptacle immersed. Spores appendaged at one end with short hyaline threads.

15. *Asteroma.*—Conceptacle very small, slightly promi-

nent, close, subconfluent, seated on more or less radiating fibrils.

16. *Discosia.*—Conceptacles innate, somewhat carbonaceous, at length collapsed and plicate, ostiole perforated. Spores fusiform, produced at both ends into a threadlike point.

17. *Prosthemium.*—Conceptacles horny, immersed, ostiole simple. Spores transversely septate, verticulate at the apex of thin filaments.

18. *Angiopoma.*—Conceptacles free, membranous, somewhat horny, cup-shaped, dehiscing by a circular mouth, provided with a fugarious epiphragm. Spores affixed at base, stalked, septate.

19. *Piggotia.*—Conceptacles irregular, thin, obsolete beneath, confluent, bursting by irregular crack; spores on short stalks, largish, obovate, somewhat constricted at base.

20. *Phlyctæna.*—Conceptacle spurious, formed by the blackened epidermis; spores fusiform, cuspidate, septate, accompanied by a gelatinous mass.

21. *Glœosporium.*—Conceptacle absent; spores covered by cuticle which separates; spores stalked, elliptical, simple, exuding a gelatinous tendril.

22. *Dilophosphora.*—Conceptacle immersed in a spurious stroma, covered, perforated by a pore; spores cylindrical, continuous, crowned at both ends with radiating filiform appendages.

23. *Sphæropsis.*—Conceptacle spherical, immersed, subinnate, astomous, bursting by separation of epidermis or irregularly. Spores simple.

Family II. MELANCONIEI.—Conceptacles as in the preceding, but without a proper perithecium; spores elongated.

Gen. 1. Sporidia globose, simple, adhering to form a nucleus, at length breaking out free. Color black.

2. *Papularia.*—Sporidia quite simple, collected in groups under epiderm of dead plants, set free in a pulverulent patch by the decay of the epidermis.

3. *Stilbospora.*—Sporidia septate (septa evanescent), full of sporidiola, adhering in a nucleus, at length breaking out.

4. *Didymosporium.*—As the last, but the sporidia didymous (septate in middle). Color black or fuscous.

5. *Cytispora.*—Sporidia simple, stick-shaped, minute, in a multilocular nucleus, at length opening by a common apical pore and emerging as a gelatinous tendril.

6. *Melasmia.*—Sporidia minute, stick-shaped, in a flat, thin nucleus, which bursts at apex and extrudes the spores in a gelatinous globule.

7. *Micropera.*—Sporidia linear, curved, formed in nuclei, bursting by distinct pores, and discharged mixed with jelly.

8. *Ceuthospora.*—Sporidia simple, ovate, contained in several globose nuclei in a common stroma, escaping by a simple lancinate pore.

9. *Nemaspora.*—Sporidia simple, spindle-shaped, in nuclei in a common grumous stroma and opening by a common pore.

10. *Discella.*—Sporidia elongated, simple or uniseptate, stalked, in a nucleus with perithecium.

11. *Cylindrosporium* (*Glœosporium*).—Sporidia simple, elliptical, stalked, in nucleus covered only by cuticle of leaf, finally extruded in a gelatinous tendril.

12. *Coryneum.*—Sporidia spindle-shaped, multiseptate, stalked, crowded, breaking out on surface as a pulvinate disk.

13. *Bactridium.*—Sporidia spindle-shaped, multiseptate, transparent at ends, tufted on a superficial creeping mycelium.

14. *Eriospora.*—Sporidia filiform, originally attached in

fours upon sporophores, in groups of globose nuclei opening by a common pore.

15. *Cheirospora.*—Sporidia simple, crowded in tufts at apex of a filiform sporophore, in moniliform rows.

Family III. PHRAGMOTRICHACEÆ.—Conceptacles horny, breaking through epidermis of leaves, etc., at first closed, then bursting longitudinally; spores septate, and in chain-like series, with paraphyses on internal walls of conceptacles.

Gen. 1. *Endotrichum.*—Conceptacle innate or immersed, bursting by a longitudinal slit; spores globular, simple.

2. *Schizothecium.*—Conceptacle superficial, bursting laterally; spores globular, simple.

3. *Pilidium.*—Conceptacles simple, sessile, rounded, bursting by stellate fission; spores spindle-shaped, simple.

4. *Excipula.*—Conceptacle cup-shaped, membranous, sessile, naked; spores spindle-shaped.

5. *Dinemasporium.*—Conceptacle cup-shaped, membranous, sessile, closed by villi, and at length open; sporigenous layer discoid, dissolving, with cylindric, elongate, filiform spores.

6. *Myxormia.*—Conceptacle thin, cup-shaped, open, formed of elongated cells. Pedicels of spores delicate. Spores oblong, chained together, at length free, involved in mucus.

7. *Cystotricha.*—Conceptacle bursting by a longitudinal slit; pedicels of spores branched, articulate, somewhat beaded.

8. *Bloxamia.*—Conceptacle delicate, hyaline, upper part evanescent and forming a rim. Spores quadrate in crowded tubules.

9. *Phragmotrichum.*—Conceptacle horny, carbonaceous, at first closed, then splitting by longitudinal fissure; fertile filaments mixed with inarticulate paraphyses; spores compound and chained in series.

Family IV. TORULACEI.—Mycelium filamentous, growing on the surface of decayed vegetables, bearing erect filaments, terminating in rows of simple or compound spores.

Gen. 1. *Torula.*—Spores in beaded chains, simple, readily separating, placed on short continuous or septate pedicel.

2. *Bispora.*—Spores uniseptate.

3. *Septonema.*—Several transverse septa in the spores.

4. *Alternaria.*—Cellular spores connected by filiform isthmus.

5. *Sporidesmium.*—Spores in tufts, straight, subclavate or fusiform, shortly stalked or sessile, transversely septate or cellular.

6. *Sporochisma.*—Filaments erect, simple, external membrane inarticulate. Spores articulate in fours.

7. *Tetraploa.*—Spores sessile, quadriseptate, in bundles of four, each crowned with a bristle.

8. *Coniothecium.*—Spores without septa, in heaps, finally separating into a powder.

9. *Echinobotryum.*—Spores rounded apiculate, in fascicles, or erect annulated filaments.

10. *Sporendonema.*—Erect filaments with single rows of spores in the interior.

11. *Spilocæa.*—Spores globose, adhering together and to the matrix, forming spots laid bare by separation of epidermis.

12. *Achorion.*—Mycelium ramose, articulated, joints terminating in round, oval, or irregular spores (conidia?).

13. *Speira.*—Spores connate in concentric filaments, forming horseshoe-like lamina, finally separating.

14. *Trimmatostroma.*—Spores curved, multiseptate, in beaded rows, separating.

15. *Gyrocerus.*—Spores connate in spirally coiled filaments, separating.

16. *Dictyosporium.*—Spores tongue-shaped, reticularly cellular.

Family V. UREDINEI.—Mycelium a filamentous mass growing in the interior of living vegetable structures, finally breaking out on the surface in patches, margined or naked, and bearing simple or compound spores, single or in beaded series.

The following is Tulasne's synopsis of the family:

I. *Albuginei* (white or pale-yellow, heterosporous).
   Gen. 1. Cystopus.

II. *Æcidinei* (with a peridium, homœsporous).
   2. Cæoma.
   3. Æcidium.
   4. Ræstelia.
   5. Peridermium.

III. *Melampsorei* (solid, pulvinate, biform).
   6. Melampsora.
   7. Coleosporium.

IV. *Phragmidiacei* (pulverulent, biform, infuscate).
   8. Phragmidium.
   9. Triphragmidium.
   10. Puccinia.
   11. Uromyces.
   12. Pileolaria.

V. *Pucciniei* (fleshy, ligulate or tremelliform, naked, and uniform in the fruits).
   13. Podisoma.
   14. Gymnosporangium.

VI. *Cronartiei* (peridiate, biform, ligulate).
   15. Cronartium.

Family VI. USTILAGINEI.—Similar to the last, but grow in the interior of organs, especially ovaries and anthers, of plants. Spores break up without bursting through to surface, so as to leave a cavity full of dustlike spores.

I. *Ustilaginei Veri.*—Stroma at first mucilaginous, entire, or soon broken up into variously conglomerated

masses, then into unappendaged spores; few or no filaments persistent.

1. *Ustilago.*—Spores simple.

2. *Thecaphora.*—Spores compound.

II. *Tilletiei.*—Stroma of interwoven fragile filaments; spores acrogenous on their ramules, often appendaged when free.

3. *Tilletia.*

Order HYPHOMYCETES.—Mycelium filamentous, growing as moulds over dead or living organic substances. The erect filaments bear terminal, free, single, simple, or septate spores.

Family I. ISARIACEI.—Receptacle clavately branched, of filaments attached in their whole length. Spores simple, attached to simple pedicels.

Gen. 1. *Isaria.*—Receptacle of interwoven filaments, or cellularly fleshy. Spores on simple sporophores arising on all sides.

2. *Anthina.*—Receptacle of parallel filaments, feathery or villous at the summit where they form the sporophores.

3. *Ceratium.*—Receptacle horn-shaped, mucilaginous, with filaments which collapse into granules (conidia), and free sporidia.

Family II. STILBACEI.—Receptacle wartlike or clavate above, stalked below, of filaments packed, coherent, terminating singly in free spores.

Gen. 1. *Stilbum.*—Receptacle clavate or capitate at summit. Spores simple.

2. *Pachnocybe.*—Receptacle stipitate, clavate, floccose, filaments twisted, head finally pruinose, with simple spores.

3. *Periconia.*—Receptacle of coalescent crowded, paral-

lel filaments, or cellularly fleshy ; spores simple, crowded, on simple sporophores arising at summit and on the stalk.

4. *Tubercularia.*—Receptacle fleshy, of continuous sterile and threadlike beaded fertile filaments. Finally indurated, floccose, with spores scattered over it, or falling into powder.

5. *Periola.*—Receptacle cellular, sessile, fertile filaments abbreviated, torulose, mixed with septate lax sterile filaments.

6. *Volutella.*—Receptacle cellular, compact, with long rigid bristles ; spores spindle-shaped, septate, on continuous short filaments, all over the receptacle.

7. *Fusarium.*—Receptacle cellular, gelatinous ; spores spindle-shaped, simple, somewhat curved, on simple filaments forming a discoid stratum.

8. *Illosporium.*—Receptacle sub-gelatinous, diffluent ; spores simple, pellucid, generally with hyaline envelope on short filaments.

9. *Epicoccum.*—Receptacle cellular, on effused patch ; spores four-sided, cellular, singly to short filaments.

Family III. DEMATIEI.—Mycelium filamentous, spores compound or simple, rising from apices of erect, solid, corticate, subopaque filaments, or produced from solution of the plants.

Gen. 1. *Cephalotrichum.* — Fertile filaments stalklike, erect, septate, terminating in a globose capitule formed by radiating forked or ternate branches bearing globular spores at the tips.

2. *Sporocybe.* — Filaments fibrous, subulate, capitate, with simple spores conglobated into a terminal head.

3. *Œdemium.*—Filaments rigid, erect, almost continuous, or annulated, bearing at the sides globular masses of spores.

4. *Myxotrichum.*—Filaments erect, scarcely septate ;

fertile branches crowned by globules of heterogeneous conglutinated spores.

5. *Dilacotricha.*—Filaments simple, uniformly articulate at apex; spores conglomerate, large, globular, shortly stalked, contents granular.

6. *Helminthosporium.*—Filaments erect, simple, septate; spores transversely septate.

7. *Triposporium.*—Filaments erect, septate, sterile branches solitary, more or less spreading; fertile branches shorter, at tips solitary, stellate, shortly stalked spores.

8. *Helicosporium.*—Filaments subulate, closely septate, diaphanous at summit; spores threadlike, septate, spirally coiled, then expanding elastically.

9. *Cladotrichum.*—Filaments septate, branched, branches and branchlets with septate spores at tips.

10. *Dematium.*—Filaments septate, with verticillate branchlets below, simple and whiplike above; spores crowded on apices of ramules.

11. *Cladosporium.*—Filaments septate above, bearing spores in rows forming short moniliform branchlets.

12. *Macrosporium.*—Filaments suberect, septate, delicate, evanescent, with erect stipitate spores, with many transverse and usually some longitudinal septa.

13. *Arthrinium.*—Filaments tufted, suberect, annulate with opaque septa; spores fusiform, septate, large.

14. *Camptoum.*—Filaments as preceding; spores ovate, curved, small.

Family IV. MUCEDINES.—Mycelium filamentous, spores solitary, or crowded on articulated or branched tubular and pellucid filaments, soon separating and mingling with the mycelium or adherent in chained rows (moulds, mildews, etc.).

A. Fertile filaments (pedicels) simple or branched, terminating in single spores, or a short row.

* Spores simple.

1. *Botrytis.*—Pedicels erect, septate, branched; branches and branchlets septate; spores solitary, on tips of branchlets, which are racemose, umbellate, cymose, etc.

2. *Peronospora.*—Like 1, but pedicels without septa.

3. *Verticillium.*—Pedicels erect, septate, with whorled branches terminating in a solitary spore or a short row of spores.

4. *Acremonium.*—Pedicels short, subulate, branches from a horizontal filament, bearing single smooth spores.

5. *Zygodesmus.*—Like 4, but with echinulate spores.

6. *Oidium.*—Pedicels simple, short, erect, clavate, septate, with one, sometimes two, oval spores.

7. *Fasidium.*—Spores elongate, fusiform.

8. *Menispora.*—Pedicels erect, septate, with fusiform or cylindric spores, at first joined in bundles.

9. *Sceptromyces.*—Pedicels erect, geniculate, verticillately branched; branches short, racemose; spores in grapelike bunches.

* * Spores septate.

10. *Brachycladium.*—Pedicels branched above, septate, moniliform; branches and branchlets forming a sporiferous capitulum; spores transversely septate.

11. *Trichothecium.*—Pedicels in tufts, the central erect, fertile; spores acrogenous, didymous, free, commonly loosely heaped.

12. *Cephalothecium.*—Pedicels simple, continuous, with terminal head of didymous spores.

B. Erect filaments (pedicels) terminating in strings of spores.

* Spores simple.

13. *Penicillium.*—Pedicels erect, septate, penicillately branched above; branches and branchlets septate; strings of spores at tips of branches.

14. *Sporotrichum.*—Pedicels simple or slightly branched, septate and articulate, articulations remote, inflated; spores simple, usually in heaps among the filaments.

15. *Briarea.*—Pedicels septate, with terminal moniliform chains of spores, crowded into a head,

16. *Gonatorrhodum.*—Pedicels septate, with chains of spores in a terminal head, and in whorls at the joints.

* * Spores septate.

17. *Dendryphium.*—Pedicels septate, unbranched; strings of spores in a bunch at apex; spores septate.

18. *Dactylium.*—Pedicels septate, branched above; strings of septate spores singly or in pairs, at apices of branches.

C. Fertile filaments (pedicels) inflated at the tips or at various points in their length, with projecting points or warts, on the inflations bearing

* Simple spores.

19. *Aspergillus.*—Pedicels continuous, erect, simple filaments, inflated into a little head at the summit, bearing moniliform chains of spores, crowded into a capitulum.

20. *Rhinotrichum.*—Pedicels erect, septate, sometimes sparingly branched, the apices clavate, cellular, bearing scattered points supporting simple spores.

21. *Papulaspora.*—Pedicels short lateral branches from a creeping filament, terminating in cellular heads beset with spores on the areolæ.

22. *Rhopalomyces.*—Pedicels erect, not septate, terminating in cellular heads, with simple spores on the areolæ.

23. *Stachylidium.*—Pedicels articulate, whorled-branched above; branches geniculate and articulate; spores subpedicilate, in little heads inserted at tips of branches.

24. *Gonatobotrys.*—Pedicels septate, with joints swollen at intervals, the swollen joints bearing globular heaps of spores on short spines spirally arranged.

25. *Acmosporium.*—Pedicels septate, branched above; branches and branchlets forming a cyme, thickened at the apex, and furnished with globular capitules covered with points; spores attached on the points of capitules.

26. *Haplotrichum.*—Pedicles septate, terminating in continuous, solitary, sporiferous head.

27. *Actinocladium.* — Pedicles septate, umbellately branched at summit; spores accumulated at tips of branches.

28. *Botryiosporium.*—Pedicles septate, with short spine-like branchlets above, spirally arranged, and terminating in four or five short points which support globular heads of spores.

* * Spores septate.

29. *Arthrobotrys.*—Pedicles simple, septate, with joints swollen at intervals and clothed with spines bearing didymous spores in globular heaps.

5. *Family Sepedoniei.*—Mycelium filamentous, spores usually heaped together on the mycelium, and apparently springing out of it, without erect pedicles.

1. *Artotrogus.*—Filaments creeping, persistent; spores from middle of filaments, simple, at length free, spinous.

2. *Sepedonium.*—Filaments woolly, septate, evanescent; spores globose, connate, scabrous, stipitate, solitary, at length heaped together.

3. *Fussisporium.*—Spores fusiform or cylindrical, glued in heaps on the gelatinous matrix.

4. *Epochnium.*—Spores heaped, oblong, apiculate, septate, adnate to the matrix, interwoven with effused, tangled, slender filaments of mycelium.

5. *Psilonia.*—Spores simple, pellucid, not glued together, at first covered with conveying filaments of mycelium.

6. *Monotospora—Eutophyte.*—Filaments creeping, evanescent; spores globose, solitary, terminal, at length free.

7. *Asterophora.*—Filaments creeping (over larger fungi); spores on short ramules, vesicular, stellate.

8. *Acrospeira.*—Filaments creeping, ramuli branched, the fertile terminating in a spiral coil of about three joints, one of which swells into a rough-coated spore.

9. *Zygodesmus.*—Filaments creeping, branched, with short ramuli bearing echinate spores, the pedicles with a lateral indentation looking like a joint.

Order PHYSOMYCETES, or *Mucoroideæ* (Moulds).—Mycelium (microscopic) filamentous, bearing stalked sacs (peridiola) containing numerous minute sporules.

Family I. ANTENNARIEI (doubtful).—Mycelium radiate or erect, bearing sessile globular peridioles, filled with ovate spores, discharged by rupture of sac at apex. Form flocculent or byssoid patches on leaves or bark, and appear to be merely states of other genera.

Family II. MUCORINI.—Mycelium filamentous, vague, giving off erect simple or branched filaments terminating in vesicular cells (peridioles) full of minute spores; often with central column in the interior. Form flocks and clouds on decaying matters-

1. *Phycomyces.*—Peridiole pear-shaped, separated from apex of pedicle by an even joint; opening by an umbilicus. Spores oblong, large. Filaments tubular, continuous, shining.

2. *Hydrophora.*—Peridiole subglobose, membranous, dehiscent, at first crystalline, aqueous, then turbid, and at length indurated; bolumella absent; spores simple, conglobated.

3. *Mucor.*—Peridiole subglobose, separating like a cap (an annular fragment attached), from the erect, simple pedicle, or bursting irregularly; columella cylindric or ovate, spores simple.

4. *Acrostalagmus* (*?*).—Peridioles globose, with a columella; at the points of doubly verticillate branches from an erect pedicle.

5. *Ægerita.*—Peridiole spherical, very fugacious; sporidia scattered like meal over the grumous receptacle.

6. *Pilobolus.*—Peridiole globular, separating like a cap from the short stalk of a single cell, attached on a unicellular ramified mycelium; columella conical; spores numerous, free in the peridiole.

7. *Syzygites.*—Filaments erect, simple, branched above, branches and branchlets di- or tri-chotomous, fertile branches forcipate, bearing pairs of opposite internal clavate branches which subsequently coalesce.

8. *Eurotium.*—Peridiole cellular, membranous, sessile, at length bursting irregularly; spores produced by a central cellular nucleus, which breaks up into numerous parent cells (asci), in which four to eight minute spores are formed, and finally set free; filaments of mycelium radiating from the base of the peridiole.

ALGÆ—SEAWEEDS, ETC.

Order I. RHODOSPERMEÆ or FLORIDEÆ.—Thallus leaflike or filamentous, rose-red or purple. Fructification consisting of: 1. Spores, mostly inclosed in conceptacles (ceramidia, coccidia, favellidia, etc.). 2. Tetraspores, red or purple (a membranous sac containing, when ripe, four spores). 3. Antheridia (pellucid sacs filled with yellow corpuscles or spermatozoids).

Families I. RHODOMELACEÆ.—*Frond* cellular, areolated or articulated. *Ceramidia* external. *Tetrapores* in rows, immersed in ramuli or contained in proper receptacles (stichidia).

1. *Odonthalia.*—*Frond* flattened, linear, with obsolete midrib, pinnatifid, alternately inciso-dentate.

O. dentata.—Color, wine-red.

2. *Rhodomela.*—*Frond* cylindric, inarticulate, opaque. Tetraspores in podlike receptacles (stichidia).

R. lycopodioides.—Purplish-brown.

R. subfusca.—Brownish or reddish.

3. *Bostrychia.*—*Frond* cylindric, inarticulate, dotted. The surface-cells quadrate. *Tetraspores* in terminal pods.

4. *Rytiphlæa.*—*Frond* cylindric, inarticulate, transversely striate. *Tetraspores* in podlike receptacles.

5. *Polysiphonia.*—*Frond* cylindric, articulate in whole or in part, the branches longitudinally striate. *Tetraspores* in distorted ramuli.

6. *Dasya.*—*Frond* cylindric, the stem inarticulate, ramuli articulate, composed of a single string of cells. *Tetraspores* in podlike receptacles (stichidia) borne by the ramuli.

2. LAURENCIACEÆ.—*Frond* cellular, continuous. *Ceramidia* external. *Tetraspores* scattered, immersed in the branches and ramuli.

1. *Bonnemaisonia.*—*Frond* solid, filiform, rose-red. Much branched; branches margined with subulate distichous cilia.

2. *Laurencia.*—*Frond* solid, cylindric, or compressed (purple or yellowish), pinnatifid. The ramuli blunt.

3. *Chrysimenia.*—*Frond* hollow, filled with mucus, neither constricted nor chambered.

4. *Chylocladia.*—*Branches* hollow, filled with mucus, constricted at intervals and chambered.

3. CORALLINACEÆ.—*Frond* calcareous or crustaceous, rigid. *Ceramidia* external, containing the tetraspores.

* *Frond* filiform, articulate.

1. *Corallina.*—*Frond* pinnated. *Ceramidia* terminal, simple.

2. *Jania.*—*Frond* dichotomous. *Ceramidia* tipped with two hornlike ramuli.

* * *Frond* crustaceous or foliaceous, opaque, not articulate.

3. *Melobesia.*—*Frond* stony, forming a crustaceous expansion, or a foliaceous or shrublike body.

4. *Hildebrandtia.*—*Frond* cartilaginous, not stony.

* * * *Frond* plain, hyaline, composed of cells radiating from a centre. *Fructification* unknown.

5. *Lithocystis* (a minute parasite).—*L. allmanni* forms minute white dots on *Chrysimenia clavelosa*, consisting of fanshaped fronds composed of square cells.

4. DELESSERICEÆ.—*Frond* cellular, continuous, areolated. *Coccidia* external. *Tetraspores* collected into definite clusters (sori).

1. *Delesseria.*—*Frond* leafy, of definite form, with percurrent midrib.

2. *Nitophyllum.*—*Frond* leafy, of indefinite form. No midrib (sometimes vague nerves).

3. *Plocamium.*—*Frond* linear or filiform, compressed. Much branched, distichous, ramuli pectinate, secund.

5. RHODYMENIACEÆ.—*Frond* cellular, continuous; the superficial cells minute. *Coccidia* external. *Tetraspores* scattered through the frond or forming undefined, cloudlike patches.

* *Frond* flat, expanded, leaflike, dichotomous or palmate.

1. *Stenogramme.*—*Conceptacles* linear, riblike.

2. *Rhodymenia.*—*Conceptacles* hemispherical, scattered.

* * *Frond* compressed or terete, linear or filiform, much branched.

3. *Sphærococcus.*—*Frond* linear, compressed, two-edged, distichously branched, with obscure midrib.

4. *Gracilaria.*—*Frond* filiform, compressed or flat, irregularly branched; the central cells very large.

5. *Hypnea.*—*Frond* filiform, irregularly branched, traversed by a fibro-cellular axis.

6. CRYPTONEMIACEÆ.—*Frond* fibro-cellular, composed of articulated fibres connected by gelatin. *Favellidia* immersed in the frond or sub-external. *Tetraspores* immersed in the frond.

1. *Sub-tribe* COCCOCARPEÆ.—*Frond* solid, dense, cartilaginous, or horny. *Favellidia* in semi-external tubercles or swellings of frond.

1. *Grateloupia.*—*Frond* pinnate, flat, narrow, dense, membrano-cartilaginous. *Favellidia* immersed in the branches, communicating with the surface by a pore. *Tetraspores* scattered.

2. *Gelidium.*—*Frond* pinnate, compressed, narrow, horny. *Favellidia* immersed in swollen ramuli. *Tetraspores* forming subdefined sori in the ramuli.

3. *Gigartina.*—*Frond* cartilaginous, cylindric, or compressed, its flesh composed of anastomosing filaments lying apart in firm gelatin. *Favellidia* in external tubercles. *Tetraspores* in dense sori sunk in the frond.

2. *Sub-tribe* SPONGIOCARPEÆ.

4. *Chondrus.*—*Frond* fan-shaped, dichotomously cleft, cartilaginous, dense. *Tetraspores* in sori immersed in substance of frond.

5. *Phyllophora.*—*Frond* stalked, rigid, membranaceous, proliferous from the disk, dense. *Tetraspores* in distinct superficial sori or in special leafletlike lobes.

6. *Peyssonelia.*—*Frond* depressed, expanded, rooting by the under surface, concentrically zoned, membranous or leathery. *Tetraspores* in superficial warts.

7. *Gymnogongrus.*—*Frond* filiform, dichotomous, horny, of dense structure. *Tetraspores* strung together, contained in superficial wartlike sori.

8. *Polyides.*—*Root* scutate. *Frond* cylindric, dichotomous, cartilaginous. *Favellæ* in spongy external warts. *Tetraspores* scattered in peripheric stratum of frond, cruciate.

9. *Furcellaria.*—*Root* branching. *Frond* cylindric, dichotomous, cartilaginous. *Favellæ* unknown. *Tetraspores* imbedded among filaments of periphery, in swollen podlike upper branches of frond, transversely zoned.

3. *Sub-tribe* GASTROCARPEÆ.—*Frond* gelatinously mem-

branous or fleshy, often of lax structure internally. *Favellidia* immersed in central substance of frond, very numerous.

10. *Dumontia.*—*Frond* cylindric, tubular, membranous. Tufts of *spores* attached to wall of tube inside.

11. *Halymenia.*—*Frond* compressed or flat, gelatino-membranaceous, surfaces separated by a few slender anastomosing filaments. Masses of *spores* attached to inner face of membranous wall.

12. *Ginannia.*—*Frond* cylindric, dichotomous, traversed by a fibrous axis, walls membranous. Masses of spores on inner face of wall.

13. *Kallymenia.*—*Frond* expanded, leaflike, fleshy-membranous, solid, dense. *Favellidia* like pimples, half immersed and scattered.

14. *Iridea.*—*Frond* expanded, leaflike, thick, fleshy-leathery, solid, dense. *Favellidia* wholly immersed, densely crowded.

15. *Catanella.*—*Frond* filiform, branched, constricted at intervals into oblong articulations; the tube filled with lax filaments.

4. *Sub-tribe* GLOIOCLADIEÆ.—*Frond* loosely gelatinous, the filaments lying apart, surrounded by a copious gelatin. *Favellidia* immersed among filaments of periphery.

16. *Cruoria.*—*Frond* crustaceous, skinlike.

17. *Naccaria.*—*Frond* filiform, solid, cellular; ramuli only composed of radiating free filaments.

18. *Gloiosiphonia.*—*Frond* tubular, hollow, walls composed of radiating filaments.

19. *Nemaleon.*—*Frond* filiform, solid, elastic, filamentous, axis of a network of anastomosing filaments; periphery of moniliform free filaments.

20. *Dudresnaia.*—*Frond* filiform, solid, gelatinous, filamentous, axis and periphery like the last.

21. *Cronania.*—*Frond* filiform, of a jointed filament, whorled at the joints, with minute multifid, gelatinous ramuli.

7. CERAMIACEÆ.—*Frond* filiform, of an articulated filament, simple, or coated with stratum of small cells. *Favellæ* naked, berrylike masses. *Tetraspores* external or partially immersed.

1. *Ptilota.*—*Frond* compressed, inarticulate, distichous, pectinato-pinnate. *Favellæ* pedunculate, involucrate.

2. *Microcladia.*—*Frond* filiform, inarticulate, dichotomous. *Favellæ* sessile, involucrate.

3. *Ceramium.*—*Frond* filiform, articulate, dichotomous; the joints opaque. *Favellæ* sessile, mostly involucrate. *Tetraspores* mostly immersed.

4. *Spyridia.*—*Frond* filiform, inarticulate; the branches clothed with minute, setiform, articulate ramelli. *Favellæ* pedunculate, involucrate. *Tetraspores* sessile on the ramelli.

5. *Griffithsia.*—*Frond* articulated, dichotomous, or clothed with whorled, dichotomous ramelli, rose-red. *Favellæ* involucrate, sessile, or pedunculate. *Tetraspores* sessile, or whorled ramelli.

6. *Wrangelia.*—*Frond* articulated, pinnate. *Favellæ* terminal, involucrate with tufts of pear-shaped spores. *Tetraspores* sessile, scattered on the ramelli.

7. *Seirospora.*—*Frond* articulated. *Tetraspores* arranged in terminal moniliform strings.

8. *Callithamnion.*—*Frond*, at least the branches and ramuli, articulate, mostly pinnated. *Favellæ* terminal or lateral, sessile without involucre (except in *C. turneri*). *Tetraspores* sessile or pedicellate, scattered.

9. *Trentepohlia.*—*Frond* articulate, branched, cells in single series. *Favellæ ?* in terminal corymbs.

8. PORPHYRACEÆ.—*Frond* plain and very thin, or tubular and filiform, purplish, with oval spores in sori and tetraspores scattered over the frond.

1. *Porphyra.*—*Frond* plain, membranous, very thin,

purple; oval spores in sori, and tetraspores (square) scattered over frond.

2. *Bangia.*—*Frond* filiform, tubular, composed of radiating cells in transverse rows, in continuous hyaline sheath.

Order II. MELANOSPOREÆ or FUCOIDEÆ.—Marine. Thallus leaflike, or cordlike, or filamentous. Olive-green or brown. Fructification varied. 1. In Fucaceæ, monœcious or diœcious conceptacles containing sporanges and antheridia; the spores being fertilized by spermatozoids after discharge of both from the parent. 2. In Laminariaceæ, etc., of collections of clavate or filiform sporanges producing zoospores, with antheridia-like Fucaceæ. 3. In Cutleriaceæ similar. 4. In Dictyotaceæ three forms resembling Florideæ; tetraspores, sporanges containing simple spores, and antheridia.

Family I. FUCACEÆ.—*Frond* leathery or membranous, cellular. *Spores* and *antheridia* together or separate in spherical cavities imbedded in the frond.

* Air-vessels stalked.

1. *Sargassum.*—Branches bearing ribbed leaves; air-vessels simple.

2. *Halidrys.*—*Frond* linear, pinnate, leafless; air-vessels divided by transverse partitions.

* * Air-vessels immersed in substance of frond, or absent.

3. *Cytoseira.*—*Root* scutate. *Frond* much branched, bushy. *Receptacles* cellular.

4. *Pycnophycus.*—*Root* branching. *Frond* cylindric. *Receptacles* cellular.

5. *Fucus.*—*Root* scutate. *Frond* dichotomous. *Receptacles* filled with mucus, traversed by jointed threads.

6. *Himanthalia.*—*Root* scutate. *Frond* cup-shaped. *Receptacles* (frondlike) long, strap-shaped, dichomotously branched.

3. DICTYOTACEÆ.—*Frond* cellular, flat, compact. *Spores, antheridia* (and *tetraspores ?*) in spots or lines (sori) on surface.

1. *Haliseris.*—*Frond* dichotomous with midrib.

2. *Padina.*—*Frond* ribless, fan-shaped, concentrically streaked. *Sori* linear, concentric, bursting through the epiderm.

3. *Zonaria.*—*Frond* ribless, lobed, concentrically striate. *Sori* roundish, with spores and jointed threads.

4. *Taonia.*—*Frond* ribless, cleft irregularly, somewhat fan-shaped. *Sori* linear, concentric, superficial, alternating with scattered spores.

5. *Dictyota.*—*Frond* ribless, dichotomous. *Sori* roundish, scattered, bursting through epiderm, or (on distinct individuals) scattered spores.

3. CUTLERIACEÆ.—*Frond* cellular, compact, ribless. Dotlike collections of *sporanges* divided into eight compartments, and *antheridia* (?) consisting of chambered filaments in groups of curved jointed hairs.

1. *Cutleria.*

4. LAMINARIACEÆ.—*Frond* leathery or gelatinous, cellular. *Unilocular sporanges* in cloudlike patches, or covering the whole surface of frond; or *multilocular sporanges* clothing the whole surface of the frond like an epidermis.

* *Frond* stalked, the stalk ending in an expanded leaflike portion.

1. *Alaria.*—*Leaf* membranous, with cartilaginous percurrent midrib.

2. *Laminaria.*—*Leaf* (simple or cleft) without any midrib.

* * *Frond* simple, leafless.

3. *Chorda.*—*Frond* cylindric, hollow, the cavity having transverse partitions.

5. DICHTYOSIPHONACEÆ.—*Frond* cylindric, branched, filamentous in structure. Ovoid *sporanges* imbedded lengthwise in substance of frond, opening by a pore on the surface.

1. *Dictyosiphon.*—*Root* a minute naked disk. *Frond* cylindric, branched. *Oosporanges* irregularly scattered, solitary or in dotlike *sori.*

2. *Striaria Oosporanges* in transverse lines on surface of frond.

6. PUNCTARIACEÆ.—*Frond* cylindric or flat, unbranched, cellular. Ovate *sporanges* in groups on the surface, intermixed with clavate filaments (*paraphyses*).

1. *Punctaria.*—*Frond* flat and leaflike. *Sporanges* scattered or in *sori.*

2. *Asperococcus.*—*Frond* membranous, tubular, cylindric, or compressed. *Sporanges* in dotlike *sori.*

3. *Litosiphon.*—*Frond* cartilaginous, filiform, subsolid. *Sporanges* scattered, almost solitary.

7. SPOROCHNACEÆ.—*Frond* leathery or membranous, cellular, branched. *Unilocular* or *multilocur sporanges* attached to external jointed filaments, free or collected in knoblike masses.

* *Sporanges* on pencilled filaments issuing from the branches (Arthrocladieæ).

1. *Demarestia.*—*Frond* solid or flat, dichotomously branched.

2. *Arthrocladia.*—*Frond* traversed by a jointed tube, filiform, nodose.

3. *Stilophora.*—*Frond* filiform, tubular or solid, branched. *Sporanges* from necklace-shaped filaments in wartlike groups on the frond.

* * *Sporanges* in knoblike receptacles composed of whorled filaments (Sporochneæ).

4. *Sporochnus.*—*Receptacles* lateral on short peduncles.

5. *Carpomitra.—Receptacles* terminal, at tips of the branches.

8. CHORDARIACEÆ.—*Frond* cartilaginous or gelatinous, of horizontal and vertical filaments (jointed) interlaced. *Unilocular sporanges* from the base of the vertical filaments forming the epiderm of the frond, and *multilocular sporanges* developed later from filaments surrounding the former.

1. *Chordaria.*—Axis cartilaginous, dense, filaments of circumference unbranched.

2. *Mesogloia.*—Axis gelatinous, loose, filaments of circumference branching.

9. MYRIONEMACEÆ.—*Frond* tubelike, crustaceous or spreading as a crust, of filamentous structure. *Unilocular* and *multilocular sporanges* attached to the superficial filaments and concealed among them.

1. *Leathesia.—Frond* tuber-shaped.

2. *Ralfsia.—Frond* crustaceous.

3. *Elachistea. Frond* parasitic, of a tubular base, bearing pencilled erect filaments.

4. *Myrionema.—Frond* parasitic, forming a flat base, bearing cushionlike tufts of decumbent filaments.

10. ECTOCARPACEÆ.—*Frond* filiform, jointed. *Unilocular sporanges*, ovate sacs at ends or intermediate joints of the filaments and *multilocular sporanges* of minute jointed filaments in similar situations. *Antheridia* with spermatozoids in *Sphacelaria.*

* *Frond* rigid, each articulation of numerous cells (*Sphacelarieæ*).

1. *Cladostephus.—Ramuli* whorled.

2. *Sphacelaria.—Ramuli* distichous, primated.

* * *Frond* flaccid, each articulation of a single cell.

3. *Ectocarpus.—Frond* branching, *ramuli* scattered.

4. *Myriotrichia.*—*Frond* unbranched, *ramuli* whorled, tipped with pellucid fibres.

Order III. CHLOROSPOREÆ or CONFERVOIDEÆ.—In sea or fresh water, or on damp surfaces, with filamentous, or more rarely a leaflike thallus; microscopic forms, sometimes pulverulent or gelatinous, consisting frequently of definitely arranged groups of distinct cells, with an ordinary structure, or with their membrane silicified (Diatomaceæ). Fructification varied.

1. *Resting spores* produced from cell-contents after fertilization either by *conjugation* or impregnation.

2. *Spermatozoids* produced from the contents of other cells.

3. *Zoospores.*—Two, four or multiciliated active gonidia, discharged from the vegetative cells without impregnation and germinating directly.

The simple vegetative increase of unicellular forms is analogous to cell division of filamentous forms.

The Volvocineæ pass the vegetative stage of existence as ciliated zoospores collected within a gelatinous common envelope.

Family I. LEMANEÆ.—*Frond* cartilaginous, leathery, inarticulate, filamentous, hollow, with whorls of warts at irregular distances, or necklace-shaped. *Fructification* tufted, simple, or branched; necklace-shaped filaments, attached to inner surface of tubular frond, and breaking up into elliptic spores. *Grow in fresh water.*

1. *Lemania.*—Two species, *L. torulosa* and *L. fluviatilis*, in clear running streams.

2. BATRACHOSPERMEÆ.—*Plants* filamentous, articulated, invested with gelatin. *Frond* of aggregated, articulate, longitudinal cells, whorled at intervals, with short, horizontal, cylindric, or beaded, jointed ramuli. *Fructification*

ovate *spores*, and tufts of *antheridial cells* (?) attached to the lateral ramuli, which consist of minute, radiating, dichotomous, beaded filaments. *Fresh-water plants.*

1. *Batrachospermum.*—Lateral whorled ramuli, beaded spores in globular knobs in the whorls.

1. *B. moniliforme.*—Color various, vaguely branched.

2. *B. giganteum.*—Large, purple when dry, long, bifurcated branches.

3. *B. affine.*

4. *B. cœrulescens.*—Æruginous, slender, branched. Upper and lower whorls confluent.

5. *B. vagum.*—Dichotomously branched, equally thick throughout; whorls all confluent.

2. *Thorea.*—Stems continuous, whorled, articulated, sometimes branched, ramuli cylindric, the spores at their bases.

3. CHÆTOPHORACEÆ.—In the sea or fresh water, coated by gelatinous substance, either filiform or (connected filaments) gelatinous, definitely formed or shapeless fronds or masses. Filaments jointed, bearing bristlelike processes. *Fructification*, zoospores from cell-contents of filaments, *resting spores* from particular cells after impregnation by ciliated spermatozoids produced in *antheridial cells.*

1. *Draparnaldia.*—Filaments free, primary nearly colorless, with tufts of colored ramuli at the joints; zoospores formed singly in the joints of the ramuli.

2. *Chætophora.*—Filaments dichotomously branched, aggregated into shapeless, incrusted or branched, gelatinous fronds, the joints bearing bristlelike branches. Zoospores (four cilia) solitary in the articulations, membranes of filaments very fugacious. (Little green protuberances on sticks, etc., in fresh water.)

C. endiviæfolia. C. tuberculosa. C. elegans. C. pisiformis. C. dilatata. C. longæva.

3. *Coleochæte.*—*Frond* disk-shaped or irregularly ex-

panded, adherent to leaves, etc., of aquatic plants, formed of jointed dichotomous filaments radiating from a centre, more or less conjointed laterally, joints producing from the back a slender truncate open tube from which a long bristle is exserted. Spores and zoospores formed in the joints.

4. *Ochlochæte.*—*Frond* discoid, appressed, filaments cylindric, radiating, irregularly branched, of a single series of cells, each of which is prolonged above into an inarticulate bristle. *O. hystrix.*

4. CONFERVACEÆ.—In sea or fresh water, filamentous, jointed, without evident gelatin. Filaments variable, simple or branched, cells more or less filled with green, or rarely brown or purple, granular matter, sometimes arranged in peculiar patterns on the walls, and convertible into spores or zoospores. Not conjugating.

1. *Cladophora.*—Filaments tufted, much branched. Sea and fresh water. Zoospores minute, many in a cell.

C. agagropila.—Dense balls in lakes, etc.

C. crispata.—Yellowish or dull-green strata.

2. *Rhizoclonium.*—Filaments decumbent, with small rootlike branches. Zoospores minute, numerous. Sea, brackish, and fresh water.

R. rivulare.—Filaments simple. Bright-green bundles, two to three feet long, in streams.

R. tortuosum.—In salt-water pools.

R. arenosum.—Dirty-green strata, on sandy seashores.

R. obtusangulum.—Sandy, seashores.

R. riparium.

R. implexum.—On mountain rocks.

R. arenicolum (ditto).

3. *Conferva.*—Filaments unbranched. Zoospores minute, numerous in the cells. Sea, brackish, and fresh water.

C. bombycina.—Yellow-green cloudy stratum in stagnant water.

C. flocosa.—More robust, articulations once or twice longer than broad.

C. æruginosa.—Yellow-green tufted filaments, thick as hog's bristles.

C. melagonium.—Erect tufted filaments.

C. linum.—Long, tangled filaments.

4. *Ulothrix* (?).—Filaments simple, often fasciculated, joints short. Zoospores four ciliated; two, four, or more in a cell. Fresh water.

5. *Stigeoclonium* (?).—Filaments branched, ramules running out into slender points, cell-walls often dissolving to emit zoospores. Zoospores four ciliated, one in a cell.

5. ZYGNEMACEÆ.—Fresh-water filaments, no evident gelatin, of a series of cylindric cells, straight or curved. Cell-contents often arranged in elegant patterns on the walls. Reproduction from conjugation followed by a true spore, in some genera dividing into four sporules.

1. *Zygnema.*—Filaments simple, green contents arranged in two globular or stellate masses in each cell. Conjugate by transverse processes. Spores in a parent cell on cross branch.

* Spores in one of parent cells.

Z. cruciata.—Spores globose.

Z. stagnalis.

Z. insignis.

Z. bicornis.

* * Spores in cross branches.

Z. immersa.

Z. conspicua.

Z. decussata.

Z. Ralfsii.

Z. pectinata.

2. *Spirogyra.*—Filaments simple, green contents in one or more spiral bands on cell-wall. Conjugate by trans-

verse processes. Spores in one of parent-cells (or occasionally in both).

* Spiral band single.

S. tenuissima. S. longata. S. inflata. S. communis. S. quinina.

* * Spirals two.

S. decemina. S. elongata.

* * * Spirals numerous.

S. nitida. S. maxima. S. bellis. S. pellucida. S. rivularis. S. curvata.

3. *Zygogonium.*—Filaments simple or slightly branched; contents diffused or in two transverse bands. Conjugate by transverse processes. Spores globose, in cross branches, or in blind lateral pouches without conjugation. *Z. ericetorum.*

4. *Mesocarpus.*—Filaments simple, with contents diffused. Conjugate by transverse processes, from which the filaments become recurved. Spores in cross branches.

M. scalaris. M. depressus.

5. *Staurocarpus.*—Filaments simple, contents diffused (rarely in moniliform lines). Conjugate by transverse processes, from which the filaments become recurved. Spores (or sporanges) square or cruciate in dilated cross branches.

S. glutinosus. S. cœrulescens. S. quadratus. S. virescens. S. gracillimus. S. gracilis.

6. *Mougeotia.*—Filaments simple, soon bent at intervals; contents mostly diffused, sometimes in several serpentine lines. Conjugate by the inosculation of filaments at the convexity of the angles. Spores not known. *M. genuflexa.*

6. ŒDOGONIACEÆ.—Simple or branched, fresh-water filamentous plants, attached, without gelatin. Cell-contents uniform, dense. Cell-division accompanied by circumcissile dehiscence of parent-cell, producing rings on the filaments. Reproduction by zoospores from contents of a cell, with a crown of cilia; resting spores in sporan-

gial cells after fecundation by ciliated spermatozoids formed in antheridial cells.

1. *Œdogonium.*—Filaments unbranched.

* Spores globular.

† Sporanges with valvular lid.

Œ. rostellatum.—Monœcious.

† † Sporanges with lateral orifice.

‡ Monœcious.

Œ. curvun. Œ. tumidulum.

‡ ‡ Gynandrosporous.

Œ. Rothii. Œ. depressum. Œ. Braunii. Œ. echinospermum.

* * Spores oval.

† Sporanges with valvular lid.

‡ Gynandrosporous.

Œ. ciliatum.

† † Sporanges with lateral orifice.

‡ Gynandrosporous.

Œ. apophysatum.

‡ ‡ Diœcious.

Œ. gemelliparum.

2. *Bulbochæta.*—Filaments branched and bearing bristle-cells with a bulbous base.

7. SIPHONACEÆ.—Sea, fresh water, or on damp ground. Membranous or horny hyaline substance, filled with green (in Saprolegnieæ colorless) granular matter. Fronds continuous tubular filaments, free, or in spongy masses of various shapes, crustaceous, globular, cylindric, or flat. Zoospores single or numerous. Resting spores in sporangial cells after impregnation by contents of antheridial cells of different form.

1. *Codium.*—Filaments green, branched, interwoven into spongiform frond, producing biciliated zoospores in sporangial cells borne on the sides of the erect clavate branches. Marine.

2. *Bryopsis.*—Filaments green, free, primately branched; two or four ciliated zoospores in extremities of branches. Marine. *B. plumosa. B. hypnoides.*

3. *Vaucheria.*—Filaments green, more or less branched, continuous, producing in apices large solitary zoospores covered with cilia, also bearing lateral, globose, sporangial cells and hooklike antheridial cells ("horns"). Marine or aquatic or on damp ground.

4. *Botrydium.*—Frond a spherical green vesicle on a ramified filamentous base, the cavity of the whole continuous, the ramified base producing new vesicles (sporanges) by stoloniferous growth. Multiplied by granular contents of vesicle discharged by rupture at the summit. Damp grounds.

5. *Hydrodictyon.*—Frond a green baglike net, with usually pentagonal open meshes, formed of cylindric cells connected by their ends. Ciliated zoospores formed in the "link"-cells, uniting and forming a miniature net before escaping from parent-cell.

6. *Achyla.*—Filaments colorless or light brownish (like mycelia of fungi); free, slightly branched. Numerous zoospores in apices of filaments, and spores in globose lateral sporangial cells. On dead flies, fishes, or sometimes on decaying vegetable matter in water. *A. prolifera.*

8. OSCILLATORIACEÆ.—Sea, fresh water, or damp ground. Gelatinous and filamentous. Filaments slender, tubular, continuous, filled with colored, granular, transversely striate substance, seldom branched, though often cohering so as to appear branched; usually massed in broad floating or sessile strata; very gelatinous; occasionally erect and tufted. More rarely in radiating series bound by firm gelatin, and then forming globose, lobed, or flat crustaceous fronds. Contents separate into roundish or lenticular gonidia.

* In fresh water or damp earth.

a. Stratum œruginous or blue-green.

O. limosa. O. tenius. O. muscorum. O. turfosa. O. decorticans.

b. Stratum dull green inclining to purple, black, or brown.

O. nigra. O. autumnalis. O. cortexta. O. ochracea.

* * Marine or in brackish water.

O. littoralis.

The above are species of Oscillatoria.

A. Oscillatorieæ.—Filaments transversely striate or moniliform, sometimes spirally curled, sheathed, or in the minute forms without evident sheaths. Spontaneous oscillating, creeping, or serpentine motion. Increase by transverse division.

1. *Bacterium.*—Filaments colorless, very small, short, wand-shaped, or longish-oval, with two to four cross striæ, exhibiting vibratory motion.

2. *Vibrio.*—Filaments colorless, very slender, moniliform. Active serpentine motion.

3. *Spirulina.*—Filaments green, very slender, continuous or moniliform, curled into a long helical or screw form ; oscillating.

4. *Didymohelix.*—Filaments brown, very slender, continuous, curled spirally and twisted in pairs.

5. *Oscillatoria.*—Filaments colored, continuous, transversely striated, readily breaking across ; a proper cellular sheath ; oscillating ; in strata imbedded in gelatin.

6. *Microcoleus.*—Filaments as in 5, but in bundles in a common gelatinous sheath, tubular and dichotomously branched. Filaments oscillating.

7. *Cœnocoleus.*—Filaments branched, contained in a tough, more or less permanent sheath, which bursts irregularly. Filaments annulated.

8. *Symploca.*—Filaments as in 5, but erect and tufted, coherent at base, bristling above.

B. LYNGBYEÆ.—Filaments motionless (?), oscillarioid, inclosed in distinct sheath, tufted or forming strata, with or without enveloping jelly.

9. *Dasyglœa.*—Filaments unbranched. Older sheaths broad, coalescent outside in amorphous gelatinous stratum.

10. *Lyngbya.*—Filaments elongated, articulated, unbranched; distinct convoluted cellulose tube; no gelatinous matrix; articulations close.

11. *Leibleinia.*—Filaments short, erect, tufted, unbranched; distinct cellulose coat; free; no jelly.

C. SCYTONEMEÆ.—Filaments articulated, simple, or branched, motionless; distinct articulations and large interstitial (propagative?) cells; sheaths soften and swell, but no gelatinous matrix.

12. *Scytonema.*—Filaments cæspitose, or, more rarely, fasciculate; a double (lamellar) gelatinous sheath, mostly closed at apex; branches continuous by lateral growing out of primary filaments, with kneelike base.

13. *Desmonema.*—Filaments branched, more or less coherent; primary branches with connecting cell at base; secondary branches without cell, annulated.

14. *Arthronema.*—Filaments articulated, simple, in short lengths, overlapping at their ends in gelatinous sheath.

15. *Petalonema.*—Filaments branched; outer sheaths of joints expanded upwards and outwards into funnel-shaped bodies, each partly overlapping its successor, forming a common obliquely lamellated and transversely barred gelatinous cylinder.

16. *Calothrix.*—Filaments closely articulated, tufted, with branches in apposition for some distance, here and there cohering laterally; sheaths firm, often dark-colored.

17. *Tolypothrix.*—Filaments free, radiantly or fastigiately branched, distinctly articulated at bases of branches, which are continuous by ex-current, not in apposition; sheaths thin, hyaline.

18. *Sirosiphon.*—Filaments single, double, or triple, in distinct common sheath, articulated, branched by lateral budding; branches divergent.

19. *Schizothrix.*—Filaments branched by division; sheaths lamellated, thick, rigid, curled, thickened below, finally longitudinally divided.

20. *Symphyosiphon.*—Filaments erect or ascending, inclosed in lamellated hard sheaths, concreted laterally at their bases, involved in jelly.

21. *Rhizonema.*—Sheath cellular, with branched and anastomosing rootlets (?); filaments annulated, interrupted here and there by a connecting cell; branches in pairs from protrusion of filament.

D. RIVULARIEÆ.—Filaments articulated; enlarged basal cell, attenuated above, connected into definite or indefinite fronds; motionless.

22. *Schizosiphon.*—Basal cells globose; filaments simple, sheathed; sheaths in groups, dark-colored, hard, open, and expanded above, and overlapping so as to form a succession of ochreæ, which have the free borders slit up into filaments or fringes; also displaying a spiral structure in dissolution.

23. *Physactis.*—Filaments whip-shaped, torulose at base; sheaths simple, gelatinous, in a globose and solid, or subsequently a bullose, vesicular frond; in globose fronds filaments radiate from centre, in vesicular from internal (lower) surface of gelatinous matrix.

24. *Ainactis.*—Filaments branched, articulate; thin sheaths in solid pulvinate frond, which is concentrically zoned by the dichotomous branching of filaments; sheaths more or less solidified by carbonate of lime; sometimes a spiral structure in dissolution.

25. *Rivularia.*—Filaments with an oval basal cell, succeeded by a cylindric *manubrium*, the remainder short, attenuated upwards (whip-shaped); sheaths sometimes

saccate below, open (not fringed) above, forming a slippery gelatinous frond.

26. *Euactis.*—Filaments whip-shaped, with repeated ochreate sheaths, forming fronds in which they radiate, and by superposition of successive generations form concentric layers; the ochreate sheaths are cartilaginous, lamellated, united laterally, funnel-shaped, fringed at open edge.

27. *Inomeria.*—Filaments whip-shaped, vertical, parallel; obscure sheaths decomposed into slender filaments, forming crustaceous fronds, becoming stony.

28. *Petronema.*—Densely cæspitose, erect, somewhat regularly branched; branches free, with obtuse rounded apices, and each with connecting cell at base; filaments annulated and growing thicker upwards.

E. LEPTOTHRICEÆ.—Doubtful Oscillatoriaceæ.

29. *Leptothrix.*—Filaments very slender, neither articulated, branched, concreted, nor sheathed.

30. *Hypheothrix.*—Filaments unbranched, inarticulate, sheathed, interwoven in more or less compact stratum.

31. *Symploca.*—Filaments unbranched, sheathed, inarticulate, concreted into branches, conjoined at their bases; sheath a simple hyaline membrane.

9. NOSTOCHACEÆ.—Gelatinous Fresh water, or in damp mosses, etc.; soft, or almost leathery, of variously curled or twisted necklace-shaped filaments, colorless or green, composed of simple (or double) rows of cells, contained in a gelatinous matrix of definite form, or heaped without order in a gelatinous mass. Some cells enlarge and form vesicular empty cells or sporangial cells; reproduce by breaking up the filaments, and, by resting spores formed singly in the sporanges.

1. *Nostoc.*—*Phycoma*, or general mass of plant in a film formed by condensation of the surface; globose, or spread

out; form variable, gelatinous or mucous, coriaceous, soft or hard, elastic, slimy, containing simple, curved, and entangled moniliform colorless or greenish filaments, composed of cells, which seem solid, imbedded in amorphous gelatinous matrix; *heterocysts* globose, interstitial, larger than ordinary joints of filaments.

N. commune. N. cæruleum. N. verruconum. N. minatissimum. N. lichenoides. N. vesicarium. N. sphæricum. N. pruniforme. N. foliacum.

2. *Monormia.*—Frond or *phycoma* definite, gelatinous, elongated, linear; spirally curled and convoluted sheath, inclosing a single moniliform filament; *heterocysts* interstitial; sporanges from joints most distant from vesicular cells. *M. intricata.*

3. *Anabaina.*—Filaments moniliform or cylindric, often curled, in formless mucous matrix, often forming a floating film, with vesicular cells (*heterocysts*) and sporangial cells.

* Without a membranous sheath.

a. *Trichormus.*—Heterocysts interstitial and terminal; sporanges first from cells most distant from heterocysts.

b. *Sphærozyga.* — Heterocysts interstitial; sporanges from nearest cells.

c. *Cylindrospermum.*—Heterocysts terminal; sporanges as last.

d. *Dolichospermum.*—Heterocysts interstitial; sporanges indefinite and unequal.

* * Filaments not included in membranous sheath.

e. *Aphanizomenon.*—Heterocysts none (?); sporanges usually simple and unequal.

f. *Spermosira.*—Heterocysts interstitial, single or in pairs; sporanges as in *Trichormus.*

10. Ulvaceæ.—Marine or fresh-water Algæ, membranous, flat, and expanded; tubular or saccate fronds, composed of polygonal cells firmly conjoined by their sides;

zoospores formed from cell-contents and breaking out from the surface, or motionless *spores* from the whole contents of a cell.

1. *Ulva.*—Frond plane, simple, or lobed, of double layer of cells, closely packed, producing zoospores. *U. lactuca.* (*latissima*) *U. Linza.*

2. *Enteromorpha.*—Frond hollow, simple, or branched, of a single layer of cells, closely packed, forming a sac or tube, with zoospores. *E. intestinalis.*

3. *Monostroma.*—Frond flat or saccate, simple or lacerate-lobed, forming a single layer of cells, which are scattered in a homogeneous membrane, with zoospores. *M. bullosum.*

4. *Prasiola.*—Frond membranous, lacerate-lobed, of single layer of cells in simple or compound lines, or groups multiple of four; spores from whole contents of cells, motionless. *P. callophylla, crispa, furfuracea,* and *stipitata.*

5. *Schizogonium.*—Frond filiform, dilated here and there into flat ribands, with two or four rows of cells; spores from whole contents, motionless. *S. percursum. S. lætevireus. S. murale.*

11. PALMELLACEÆ.—Plants forming gelatinous or pulverulent crusts on damp surfaces of stone, wood, etc. Masses of gelatinous substance, or pseudo-membranous expansions or fronds, of flat, globular, or tubular form, of one or numerous cells, with green, red, or yellowish contents; spherical or elliptical form, the simplest being isolated cells (in groups of two, four, eight, etc.); others formed of some multiple of four, the highest of compact, numerous, more or less closely conjoined cells. Reproduce by cell-division, by conversion of cell-contents into zoospores, and, by resting spores formed sometimes after conjugation, in other cases probably after fecundation by spermatozoids.

* Plants with a frond of colorless gelatinous substance.

† Frond amorphous.

1. *Palmella.*—Frond a slimy stratum, crowded with large globular cells, multiplying by division; green and red. *P. cruenta.*

2. *Microhaloa.* — Frond mucoid, floating in water, crowded with minute cells, multiplying by division; green and red.

† † Frond definite.

3. *Glœocarpus.*—Frond of cells in wide gelatinous coats, inclosed in similar coats of parent-cells for several generations.

4. *Botrydina.*—Frond globose, the periphery of cells cohering into a sort of cellular epiderm, the inner cells free.

5. *Clathrocystis.*—Frond gelatinous, first globose, then hollow, then broken by irregular expansion into a coarse net, finally breaking up; frond crowded with minute cells, multiplied by division.

6. *Coccochloris.*—Frond globose, gelatinous, containing numerous distinct cells, all free.

7. *Merismopœdia.*—Frond very minute, flat, square, gelatinous; cells in families of four, sixteen, and sixty-four.

8. *Urococcus.* — Frond of streaked gelatinous tubes, formed of ensheathing parent-cell membrane in a single row, with cells solitary or binary (from division) in ends of the tubes.

9. *Hormospora.*—Frond a wide, gelatinous, simple, or branched sheath, with single row of cells in twos or fours.

10. *Tetraspora.*—Frond gelatinous, more or less foliaceous; cells in fours, ultimately becoming free as zoospores.

11. *Hydrurus.*—Frond toughly gelatinous, filiform, with imbedded longitudinal rows of cells.

12. *Palmodictyon.*—Frond gelatinous, filiform, branched; branches dividing and anastomosing into a net, consisting of large vesicular cells with colored contents, which escape as zoospores.

* * Plants of single cells, solitary, or united in small numbers into families. (Unicellular Algæ.)

† Solitary cells.

13. *Schizochlamys.*—Cells free, globular, aggregated in jelly, each dividing into two or four, set free by parent-cell breaking into two or four segments; green.

14. *Chlorosphæra.*—Unicellular, free; a large globose cell with green contents, dividing into two, in each of which is formed a new cell like the parent, set free by lateral rupture of parent-cell membranes.

15. *Characium.*—Unicellular; a minute, attached, pyriform, fusiform, or subglobose sac, shortly stipitate, containing green protoplasm, which by oft-repeated binary division forms a swarm of active two-ciliated zoospores, escaping by a lateral or terminal slit.

16. *Apiocystis.*—Simple attached sac with stout membrane; green contents; at first groups of four still gonidia, which subdivide repeatedly, and as the parent-sac grows become active zoospores, which move in parent-sac, and then break out in a swarm.

17. *Coliolum.*—Attached, small, long, clavate sac, attenuated below into a solid stipe, filled with granular green contents and starch granules, ultimately converted at once into many gonidia, escaping by rupture of apex; gonidia globose.

18. *Hydrocytium.*—Attached minute oblong sac; short hyaline stalk; green contents; parietal starch-corpuscle; contents divided at once into many two-ciliated zoospores, lying on the wall, then moving actively and breaking out into a swarm.

19. *Ophiocytium.*—Minute, elongated, cylindric, curved sac; short stipe; free or attached; green contents scattered; finally eight gonidia in a single row, set free by circumcissile rupture of end of sac.

20. *Sciadium.*—First a minute, solitary, attached, elongate, tubular, stipitate sac, with eight gonidia in single

row; apex of sac opens by circumcision, and the gonidia grow out into tubes like the parent in an umbel, their stipes remaining inserted: each new tube repeats this to fourth or more generation, the last generation from the compound umbel emitting its gonidia as two-ciliated zoospores.

21. *Chytridium.*—Parasitic; minute globular pyriform or urceolate sac, attached by a foot which penetrates into the supporting body (mostly a Confervoid); cell-contents colorless, becoming two-ciliated zoospores, escaping by dehiscence of a valvelike lid, or by simple rupture of sac.

22. *Pythium.*—Parasitic; a globular sac in the interior of cell of diseased Confervoids, often in groups; contents colorless; sac grows to flasklike form, the neck perforating the wall of the nurse-plant and bursting to emit active gonidia (?).

12. VOLVOCINEÆ.—Microscopic, cellular; fresh-water groups of bodies, like zoospores, connected into four by enveloping membranes; either assemblages of coated zoospores by cohering membranes, or of naked zoospores in a common membrane; the zoospore-like two-ciliated bodies perforate the coat, and by conjoined action move the entire group; reproduce by division (*Gonium*), or by single cells becoming families (*Pandorina*, *Volvox*), and, by resting spores, formed after impregnation of some cells by spermatozoids formed from contents of other cells.

Solitary:

No cilia, *Gyges*.

A pair of cilia, PROTOCOCCUS.

Grouped:

Square layer, gonidia of 2 cilia, GONIUM.

Forming a spherical body:
Cilium solitary.
With a tail, *Uroglena.*
Without a tail.
Without eye-spot.
With special coats, *Syncrypta.*
With eye-spot.
Gonidia dividing into clusters, *Spharosira.*
Cilia 2.
No eye-spot, *Synura.*
With eye-spot.
Common envelope spherical.
Gonidia numerous, all over periphery, VOLVOX.
Gonidia 8, in a circle at the equator, STEPHANOSPHÆRA.
Envelope ellipsoidal, gonidia 16 or 32, perhaps stages of Volvox or Pandorina.

13. DESMIDIACEÆ.—Microscopic, gelatinous, green; cells without siliceous coat; forms varied, as oval, crescentic, cylindric, etc., with a more or less stellate appearance, having a bilateral symmetry, the junction being marked by a division of the green contents; individual cells free or grouped. Reproduction by *division* and by *resting spores* produced in sporangia formed after conjugation of two cells and union of their contents, and by *zoospores* formed in the vegetative cells or in the germinating resting spores.

I. CLOSTERIEÆ.—Cells single, elongated, never spinous, often not constricted in the middle; sporangia smooth.

1. *Closterium.*—Cell crescent-shaped, or much attenuated at the ends, not constricted in the middle.

2. *Penium.*—Cell straight, not, or very little constricted in the middle, rounded at both ends.

3. *Tetmemorus.*—Cell straight, constricted, notched at ends.

4. *Docidium*.—Cell straight, constricted, truncate at ends.

5. *Spirotænia*.—Cell straight, not constricted; endochrome spiral.

II. COSMARIEÆ.—Cells single, distinctly constricted in the middle; segments seldom longer than broad; sporangia spinous or tuberculated.

6. *Micrasterias*.—Lobes of the segments incised or bidentate.

7. *Euastrum*.—Segments sinuated, generally notched at ends, and with inflated protuberances.

8. *Cosmarium*.—Segments neither notched nor sinuated, end view elliptic, circular, or cruciform.

9. *Xanthidium*.—Segments compressed, entire, spinous.

10. *Arthrodesmus*.—Segments compressed, each with only two spines.

11. *Staurastrum*.—End view angular, radiate, or with elongated processes which are never in pairs.

12. *Didymodadon*.—End view angular, each angle with two processes, one inferior and parallel with that of other segment, the other superior and divergent.

III. DESMIDIEÆ.—Cells united into an elongated jointed filament; sporangia spherical, smooth.

13. *Hyalotheca*.—Filament cylindric.

14. *Didymoprium*.—Filament cylindric or subcylindric; cells with two opposite bidentate projections.

15. *Desmidium*.—Filament triangular or quadrangular; cells with two opposite bidentate projections.

16. *Aptogonum*.—Filament triangular or plane, with foramina between the joints.

17. *Sphærozosma*.—Filament plane; margins incised or sinuate; joints with junction glands.

IV. ANKISTRODESMIÆ. — Cells elongate, entire, small, grouped in fagot-like bundles.

18. *Ankistrodesmus.*

V. PEDIASTREÆ.—Cells grouped in the form of a disk or star, or placed side by side in one or two short rows.

19. *Pediastrum.*—Cells forming a disk or star, marginal cells bidentate.

20. *Monactinus.*—Cells as in 19, but marginal cells unidentate.

21. *Scenedesmus.*—Cells placed side by side in one or two rows.

14. DIATOMACEÆ.—For genera, see page 142.

INDEX AND GLOSSARY

OF TERMS USED IN THE MICROSCOPIC SCIENCES.

The figures refer to the page.

Aberration, 22 (Lat. *ab*, from, and *erro*, to wander).—Errors resulting from imperfection of lenses.

Aberrant.—Differing from customary structure.

Abnormal (Lat. *ab*, and *norma*, a rule).—Contrary to usual structure.

Abiogenesis, 125 (Gr. *a*, privative; *bios*, life; and *gennao*, to produce).—Spontaneous generation, or production without pre-existing life.

Absorption Bands, 18, 45, 101.—Lines, more or less distinct, produced in the spectrum by certain transparent substances.

Abranchiate (Gr. *a*, without; *bragchia*, gills).

Acalephs, 166 (Gr. *akalephe*, a nettle).—Sea nettles, or jelly-fish. Their power of stinging is caused by microscopic thread-cells in the integument.

Acanthocephali, 335 (Gr. *akantha*, a spine, and *kephale*, a head).—An order of parasitic worms.

Acanthaceæ.—A natural order of plants. The seeds of many genera have hygroscopic hairs with spiral fibres, which make them interesting microscopic objects.

Acarinæ, 179, 338 (Gr. *akari*, a mite).—An order of the Arachnidæ, of which the cheese-mite is the type.

Acephalocyst (Gr. *a*, *kephale*, *kustis*, a headless bladder).—Simple sacs filled with transparent liquid, usually known as hydatids. They are the cysts of *Echinococci*, in which the animals have disappeared or have been overlooked.

Acetic acid, 67.

Acetate of potass, 75.

Achyla, 136.—Microscopic plants, either Algæ or fungi, found parasitically on the bodies of dead flies in water, also on fish, etc.

Achorion Schœnleinii, 329.—A microscopic vegetation occurring in *favus* a skin disease.

Achromatic (Gr. *a*, and *chroma*, color).—Without chromatic aberration.

Achromatic object-glasses, 25.

" *condenser*, 33.

Acinetæ, 162 (Gr. *akinete*, fixed).—Infusorial animals, formerly supposed to be intermediate stages in the development of Vorticellæ.

Accessories, microscopic, 32.

Actinia, 165 (Gr. *aktin*, a sun ray).—Sea anemones, or Actinoid polyps. Formerly called animal flowers.

Acids, tests for, 109.

Adenoma, 272, 287 (Gr. *aden*, a gland).—A glandular tumor.

Adenoid Tissue, 194.—Glandular tissue.

Adulteration of food, 323.

Adjustment, 51.

Ecidium, 363 (Gr. *wheel-like*).—Minute parasitic fungi (Order, *Coniomycetes* or *Uredineæ*, like little cups with reddish or brownish spores when mature. Earlier they are minute spots on the plants they infest. Known as "blight," "brand," etc.

Ætiology, 321 (Gr. *treatise on causes*).—The doctrine of the causes of disease.

Æroscope, 321.

Agriculture, microscope in, 18.

Air-pump, 79.

Albuminous infiltration, 244.

" *compounds*, 184.

Albuminuria, 303.

Alcohol, 68, 108, 252.

" *and acetic acid*, 68.

" *and soda*, 68.

Alkalies, tests for, 108.

Alkaloids, tests for, 18, 111.

Allantois, 204 (Gr. *sausage-like*).—An oblong sac developed in the embryonic life of animals near the end of the intestine, and serving for temporary respiration.

Alcyonium, 165.—A genus of Coralline polyps.

Algæ, 139 (Lat. *sea weeds*).—The great variety in form and organization shown by this class of plants render it an interesting field of microscopic research. The families of Desmids and Diatoms have been particular favorites.

Alternation of Generations, 126.—This term denotes a form of reproduction in which the young do not resemble the parent of the animal but the grandparent.

Alimentary canal in insects, 177.

Amides, 184.—A term used in chemistry to express a compound ammonia, in which one, two, or three of the hydrogen atoms are replaced by an acid radical.

Ammonia.—Volatile alkali. Used in preparing carmine fluids, 69, 72. Test for ammonia, 107. Used as a test, 108, 111, 112. The crystals of ammoniacal salts are often beautiful microscopic objects. The hydrochlorate forms cubes, octahedra, and trapezohedra, but if crystallized rapidly makes peculiar feathery crystals. It does not polarize. Crystals of oxalate, oxalurate, and purpurate of ammonia are beautiful objects for the polariscope.

Ambulacra (Lat. *ambulacrum*, a place for walking).—Holes or avenues in the shell through which the tube feet of Echinoderms are protruded.

Amnion, 204 (Gr. *amnos*, a lamb).—One of the fetal membranes of the higher vertebrates.

Amœba, 121 (Gr. *amoibos*, changing).—Animals of simplest form, composed of a glutinous living substance or bioplasm.

Amœboid Cells, 121, 128.—Cells with movements similar to Amœba have been found in vegetables as well as animals. See Bioplasm.

Amplifier, 26, 346.

Amphipleura Pellucida, 56.—A test diatom for high powers. The valves are linear lanceolate, with a median longitudinal line. No median nodule. The striæ are exceedingly fine.

Amylum, 132 (Gr. *amuloa*, starch).—Starch.

Amyloid.—A vegetable substance analogous to starch, but turning yellow in water after having been colored blue by iodine.

Amyloid Cell and Infiltration, 239.—A waxy or lardaceous albuminate infiltrated among the tissues.

Analogy.—Resemblance in form but not in function, or in function but not in form.

Analysis of urine, 300.

Analytic Crystals, 90, 113.—Crystals which analyze polarized light, as tourmaline, nitrate of potass, boracic acid, uric acid, iododisulphate of quinia.

Anatomy of insects, 177.

Angioma, 269 (Gr. *angion*, a vessel).—Blood tumor.

Anguillula, 171 (Lat. *anguis*, a snake).—A genus of minute animals, formerly classed among Infusoria, but now regarded as nematoid Entozoa. The "eels" in sour paste and vinegar belong here.

Angular Aperture, 25.—The angle measured by the arc of a circle, the centre of which is formed by the focal point of the objective, the radii being formed by the most extreme lateral rays which the object-glass admits.

Anilin Staining-fluids, 69. *Anilin Carmine*, 69.—Anilin colors are of great interest in chemistry and microscopy. Anilin is a base, forming salts with various acids, as hydrochlorate, nitrate, and oxalate of anilin. The substitution derivatives of anilin are very complex and their colors various. Mauvine forms a purple solution; rosanilin, known also as fuchsin, magenta, etc., a deep red; Hoffman's violet a rich violet; anilin blues are numerous. There are also several anilin greens, and chrysanilin dyes a golden yellow.

Animal parasites, 330.

Animalcule, 160.—(A little animal.) Usually applied to Infusoria, Rotatoria, etc., but formerly given also to many of the lower Algæ.

Animalcule cage, 41.

Animal histology, 182.

Annelidæ, 337.—A gallicized form of Annulata.

Annulata, 172.—Ringed worms.

Annual Rings, 156.—Concentric rings seen in sections of Dicotyledonous stems. They probably indicate periods of foliage, and more than one may be produced in a year.

Androspore, 152 (Gr. *a male seed*).—A peculiar body set free from a germ-cell during the development of Œdogonium, and probably some other Confervaceæ.

Annulus of Ferns, 155.—The ring surrounding the capsule which contains the spores.

Anomalous.—Irregular, contrary to rule.

Antennæ, 175 (Lat. *antenna*, a yard-arm).—The jointed horns or feelers of most Articulata.

Anther, 157 (Gr. *anthos*, a flower).—The case which contains the pollen of a plant.

Antheridia, 154.—The so-called male organs of urn mosses and similar plants.

Antherozoids, 152.—The fertilizing cells of some of the Confervaceæ. Used also synonymously with Spermatozoids.

Aphides, 126.—Plant lice. Order, Hemiptera. Their production is an example of the alternation of generation as well as parthenogenesis.

Aphtha, 329 (Gr. *to fasten upon*).—Thrush, or muguet, a disease of the mouth, etc., in children, or in adults towards the fatal termination of chronic disease. Supposed to be the product of Oidium albicans, or thrush fungus.

Aplanatic, 26 (Gr. *without deviation*).—Refers generally to spherical aberration in lenses.

Apothecia, 154.—The shields of Lichens; firm horny disks arising from the thallus, etc., containing spores.

Aqueous humor, 220.

Arachnida, 338 (Gr. *arachne*, the spider).—The class of animals containing spiders, scorpions, mites, etc.

Arachnoid Membrane, 225.—A delicate cobweb-like membrane between the pia mater and dura mater of the brain.

Arachnoidiscus, 148.—A beautiful circular Diatom. The markings vary. A. Ehrenbergii is common on the Pacific coast.

Arcella, 159 (Lat. *arca*, a chest).—A genus of Rhizopods. The test of the common species, A. vulgaris, has delicate markings like the valves of Diatoms.

Archeus, 116.—In the theory of Van Helmont, the specific agent presiding over vital functions.

Archegonium, 155 (Gr. *arche*, beginning; *gone*, seed).—The early condition of the spore-case in mosses, ferns, etc. Also called *Pistillidium*.

Arteries, 201.—Tubes conveying blood from the heart to the capillaries. They have three coats, an outer, middle, and inner coat. The inner is epithelial, the middle of unstriped muscle, and the outer of fibrous connective tissue. They are all supplied with nutrient bloodvessels, the *vasa vasorum*, and have nerves from the ganglionic and spinal systems.

Arsenic, Tests for, 110.—Arsenious acid. The most common form of crystal is octohedral or tetrahedral, but a right rhombic form may be obtained by sublimation. Protoxide of antimony will also yield by sublimation similar crystals, requiring discrimination in cases of poisoning.

Arthritic deposits, 241 (Gr. *arthron*, a joint).

Areolar fibroma, 268.

Ascaris, 336 (Gr. *askeris*, a round worm).

Asci, 154 (Gr. *askos*, a bottle).—A long or roundish spore-case of fungi, containing spores. Called also *thecæ*.

Ascomycetes, 138.—An order of fungi characterized by *asci*.

Asellus, 172.—A. vulgaris, or water woodlouse, an Isopod crustacean, is interesting to the microscopist since its transparency permits a view of the circulation.

Aspergillus, 136, 325.—A genus of Mucedines, forming moulds, as the blue mould on cheese, etc.

Asterias, 168 (Gr. *aster*, a star).—Star-fish.

Atheroma, 234 (Gr. *porridge of meal*).—A disease of the arteries characterized by a pulpy deposit.

Atrophy of heart, 242 (Gr. *a trophe*, not nourishing).

Avanturine.—A mineral sometimes seen in cabinets consisting of silex and scales of mica. Artificial avanturine is of glass with crystals of metallic copper scattered through it.

Avicularia, 169 (Lat. *avicula*, a little bird).—The bird's-head processes of the Polyzoa.

Bacillaria, 144 (Lat. *bacillum*, a little staff).—A genus of Diatomaceæ.

Bacillus, 297, 327.—A genus of Schizomycetous Fungi.

Bacterium, 135, 161, 315, 327 (Gr. *bacterion*, a staff).—A genus of Schizomycetous Fungi. These rodlike, moving filaments have been referred to the Algæ as well as to the animal kingdom. Their nature is very obscure. See p. 135.

Balsam (Canada), Liquid resin of *Pinus balsamea*, 73.

Balsam cement, 76.

Balsam mounting, 79.

Balanus, 174 (Gr. *balanos*, an acorn).—The acorn-shell,—a family of Cirrhipeda.

Bathybius, 96, 158.—Gelatinous matter from the bed of the Atlantic Ocean, supposed by Huxley to be of the family of Rhizopods. Its animal nature is disputed.

Beale's generalization in biology, 118.

Beale on Inflammation, 248.

Beale's carmine fluid, 69.

" *injecting fluids*, 72.

" *tint-glass camera*, 40.

Beck's microscope, 32.

" *economic microscope, etc.*, 345.

" *iris diaphragm*, 33.

" *illuminator*, 38.

Bedbug, 339.—*Cimex Lectularius.*

Bell's cement, 76.

Beroe, 167.—Formerly classed among the cilograde Acalephs, now generally in the class (Ctenophora) of the sub-kingdom Cœlenterata.

Bergmehl, 94.—Mountain flour. A powdery mineral, consisting largely of the silicious valves of Diatoms. In times of scarcity in some countries it is mixed with food.

Bile in urine, 303.

Binocular Microscope, 30 (Lat. *binus*, two; *oculus*, eye).

" *Eye-piece*, 30.

Bichromate of Potash, 68.

Bipinnaria, 168.—The larval form of the star-fish, named from the symmetry of its swimming organs. The star-fish is developed around the stomach of the larva.

Biology, The Microscope in, 18, 116 (Gr. *bios*, life, and *logos*, discourse).

Bioplasm—living matter, 118, 122, 183.
" as germs of disease, 339.
Bismuth test, 306.
Blastema, 124 (Gr. *blastos*, a bud).—A term given by the early histologists to the fluid from which it was supposed cells sprouted spontaneously.
Blastoderm, 201.—The membrane of the ovum from which all the tissues sprout or originate.
Blight, 136.—A term loosely applied to a variety of diseases in plants, as well as to the causes of such diseases, as insects (animal blights) and parasitic fungi.
Bladder, 212.
Blood, 186.
Bloodvessels, 208.
Blood in disease, 295.
Blood-tests, 102, 105, 299.
Bone, 97, 195.
Boracic acid, 68,
Borax and carmine fluid, 69.
Botrytis, 18, 136.
Bowman's glands, 219.
Brain softening, 235.
Branchia (Gr. *bragchia*, the gill of a fish).—A respiratory organ adapted to breathe air dissolved in water.
Brunswick black, 76.
Bread, 323.—Adulteration of flour is readily determined, but the baking of bread affects the form of the starch-grains. Various parasitic fungi and their spores may sometimes be found on bread.
Brunonian movement, 53, 120.—Molecular motion of particles suspended in fluid.
Bryozoa, 168 (Gr. *bruon*, moss; *zoon*, animal).
Buds, sections of, 157.
Bullseye condenser, 36.
Bunt, 136.
Cabinet, 81.
Calcium, chloride of, 75.
Calyptra, 154.—The hood of an urn-moss.

Cambium.—The viscid fluid between the bark and wood of Exogens, when new wood is forming.

Camera lucida, 39.—Used in microscopy for drawing the optical image produced by it.

Calcification, 234, 241.—Infiltration of animal tissues with salts of lime.

Camphor, 133.

Canada balsam, 73.

Cancer, 288 (Lat. *cancer*, a crab).—A malignant new formation.

Canaliculi of bone, 196.

Capillaries, 201.—Minute vessels between the terminal arteries and veins.

Carbolic acid, 74.

Carbo-hydrates, 184.

Carmine fluids, 69.—Carmine is a pigment made from cochineal.

Cartilage, 195.

Catarrh, 254 (Gr. *kata*, down, and *rheo*, to flow).

Caseation, 233, 253.—Transformation of a fatty into a cheesy substance.

Carbuncle, 298.

Carbonate of lime, 99, 314.

Caustic potash, 67.

Cauliflower excrescence, 295.

Cavernous tumor, 270.

Cavities in crystals, 89.

Cells, 77 (Lat. *cellar*, a little chamber).

Cell, 117, 118.—The elementary unit of organic structure.

" structure, 119.

" genesis, 124.

" wall, in plants, 129.

Cellulose, 67, 129.—The proximate principle of cell-membrane in plants, and of the mantle of Tunicata.

Cellular plants, 134.

Cements, 75.

Cercomonas, 331 (Gr. *kerkos*, the tail; *monas*, unity.—A tailed infusorial monad.

Cerebellum, 216.
Cerebral nerves, 216.
Cestum veneris, 167.
Cephalopoda, 171 (Gr. *kephale*, head; *poda*, feet).
Characeæ, 154.
Chalk strata, 95.
Chemical reagents, 67.
" *tests*, 106.
" *products of decay*, 231.
Chloride of sodium, 68.
" " *gold*, 70.
Chlorophyll, 133 (Gr. *chloros*, green; *phyllos*, leaf).—The green coloring-matter of plants.
Cholesterin, 233 (Gr. *chole*, bile, and *stear*, suet).
Chlorides in urine, 302, 314.
Chromic acid, 66, 67.
Chloride of calcium, 75.
Chorion, 204 (Gr. *chorion*, skin).
Chyle, 190 (Gr. *chulos*, juice).
Cicatricial tissue, 262.
Cilia, 124, 191 (Lat. *cilium*, an eyelash).—Minute, hairlike bodies, on cells.
Ciliograda, 167 (Lat. *cilium*, and *gradior*, I walk).
Ciliated epithelium, 191.
Cirrigrada, 167 (Lat. *cirrus*, a curl or tendril).
Cirrhipeds, 174 (Lat. *cirrus*, and *pes*, a foot).
Cirrhosis of Liver (252).—Shrinking of the liver.
Circulation, 187.
Classes of microscopes, 28.
Ciliary motion, 161, 170.
Cleaning covers, 77.
Cleavage of yelk, 201.
Cloudy swelling, 244.
Coal, 92.
Coccoliths, 96 (Gr. *kokkos*, a berry; *lithos*, a stone).
Cochlea, 222 (Gr. *kochlos*, a spiral shell).
Coddington lens, 23, 82.
Colors of flowers, 133.
Coloring matter, 184.

Collomia seeds, 130.
Colloid degeneration, 236 (Gr. *kolla*, glue).
" *tumors*, 238.
" " *of ovary*, 239.
" *cancer*, 293.
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Collins's Harley microscope, 32.
" *graduating diaphragm*, 32.
Compound microscope, 23.
" *crystals*, 89.
" *tissues*, 197.
" *eyes*, 176.
Condensers, *Achromatic*, 33.
" *Webster's*, 34.
" *Reade's*, 34.
Condensing lens, 37.
Coniferæ, 131.
Conidia, 137.—Reproductive granules of fungi and lichens.
Conjugation of cells, 140.
" *in infusoria*, 162.
Connective tissues, 67, 192.
Conchifera, 170 (Gr. *concha*, a shell; *fero*, I carry).
Contagium vivum, 339.
Condensing prism, 35, 347.
Correlation of force, 117.
Cornea, 220 (Lat. *cornu*, a horn).
Coral, 164.
Corpus luteum, 215.
Cossus ligniperda, 179.
Corti's organ, 223.
Corns, 192, 286.
Crinoids, 167 (Gr. *krinos*, a lily; *eidos*, form).
Croupous exudation, 257.
" *pneumonia*, 259.
Cuttle-fish bone, 170.
Crystalline forms, 86, 114.
Crystallization, 100.
Crystallography, 89.
Crystalloid, 66.—Capable of crystallization.

Cryptogamia, 152 (Gr. *kryptos*, hidden, and *gamos*, marriage).—Plants with inconspicuous sexual organs.
Crustacea, 172.
Cyclops, 173.
Cypris, 173.
Cystin, 314.
Cryptococcus, 325.
Cyclosis, 129.—Fluid circulation in plant-cells.
Dammar mounting, 74, 79.
Darker's selenite stage, 44.
Dark-ground illumination, 35.
Daphnia, 173.—A genus of microscopic Crustaceans. The water flea.
Deane's compound, 74.
Dead cells, 229.
" cell-membrane, 230.
Decapoda, 174 (Gr. *deka*, ten; *poda*, feet).
Decaying protoplasm, 229.
" *nerve*, 230.
" *fat-cells*, 231.
" *connective tissue*, 231.
" *elastic fibre*, 231.
" *cartilage*, 231.
" *bone*, 231.
Decomposing blood, 229.
Degeneration of tissues, 232.
Demodex folliculorum, 179.
Definition, 54.—Power to give a distinct image.
Dental tissue, 192.
Dentine, 196.
Development of tissues, 201.
Dentzia scabra, 132.
Development of fungi, 137.
Desmidiaceæ, 140.—A family of Confervoid Algæ. Microscopic fresh-water organisms, generally green; epidermis not silicious, as is the case with Diatoms. Reproduce by cell-division, by zoospores, and by conjugation. The latter form produces a sporangium, which is sometimes spiny, and has been described as a species of Xanthidium.

Family 1. *Closterieæ.*—Cells single, elongated, never spinous, frequently not constricted in the middle; sporangia smooth.

Gen.—Closterium. Penium. Tetmemorus. Docidium. Spirotænia.

Family 2. *Cosmarieæ.*—Cells single, constricted in the middle; sporangia spinous or tuberculated.

Gen.—Micrasterias. Euastrum. Cosmarium. Xanthidium. Arthrodesmus. Staurastrum. Didymocladon.

Family 3. *Desmideæ.*—Cells united into a filament, sporangia spherical, smooth.

Gen.—Hyalotheca. Didymoprium. Desmidium. Aptogonum. Sphœrozosma.

Family 4. *Ankistrodesmiæ.*—Cells elongated, entire, small, in fagot-like groups.

Gen.—Ankistrodesmus.

Family 5. *Pediastreæ.*—Cells grouped in form of a disk or star, or side by side in one or two short rows.

Gen.—Pediastrum. Monactinus. Scenedesmus.

Diabetic sugar, 305.

Diagnosis, microscope in, 295.

Diaphragm, Rotary, 32.—An instrument for intercepting excessive rays of light.

Diaphragm, cylinder, 32.

" *graduating*, 33.

" *iris*, 33.

Diatomaceæ, 56, 94, 141.—A family of Algæ.

Diffraction of Light, 54.—Disturbance of the ray by the edge of an opaque body.

Difflugia, 159.

Diphtheritic exudation, 260.

Discrimination of blood, 299.

Distomum, 335 (Gr. *dis*, double; *stomata*, mouths).

Disease germs, 339.

Dotted cells, 130.

" *ducts*, 131.

Double Refraction, 91.—The power some crystals have of exhibiting two images.

Double staining, 347.

Duchenne's trocar, 234.

Dytiscus, 177 (Gr. *dytiskos*, diving).

Ear, 222.

Earths, analysis of, 99.

Echinococcus, 171, 333 (Gr. *echinos*, a hedgehog; *kokkus*, a berry).—Larval forms (scolices) of tapeworms, known as "hydatids."

Echinodermata, 167 (Gr. *echinos*, and *derma*, skin).—Spiny-skinned animals.

Ectosarc, 158 (Gr. *ektos*, outside; *sarx*, flesh).

Eczema, 256.—A vesicular eruption on the skin.

Eggs of Insects, 175.—These are interesting microscopic objects from the variety of their forms, colors, and markings, and the singular lids of many of them. The markings are analogous to other unicellular organisms, as spores, pollen grains, Desmids, and Diatoms.

Elastic fibres, 194.

Elaters, 154 (Gr. *elater*, an impeller).—In the Equisetaceæ, elaters are four elastic filaments attached to the spore, which, by their uncoiling, jerk the spore away from its position. They seem to be formed by spiral fissures in the outer coat of the spore. In liverworts (Hepaticeæ) they are elastic fibres coiled in membranous tubes, and originate as spiral fibres of vessels. They are supposed to assist in the dispersion of spores.

Elytra, 175 (Gr. *elution*, a sheath).

Electrical cement, 76.

Elephantiasis, 270.—A species of leprosy or skin disease.

Embryology, 204 (Gr. *en*, in; *bruo*, I swell).

Embolism, 272.—Result of occluding clots in bloodvessels.

Embryonic cells, 263.

Enchondroma, 278.—Cartilaginous tumor.

Encephalon, development of, 203 (Gr. *egcephalos*, brain).

Encephaloid cancer, 292.

Endochrome, 152.—Used for cell-contents of Algæ.

Endogenous stems, 156 (Gr. *endon*, within; *gennao*, I bring forth).

Endosmose, 129 (Gr. *endon; otheo*, I push).—The current flowing inwards when diffusion of fluids occurs through a membrane.

Endothelium, 202 (Gr. *endon; thallo*, I bloom).
Entomostraca, 173.—A family of Crustacea.
Entozoa, 171, 330 (Gr. *entos*, within, and *zoon*, an animal).
Epiderm, development of, 203.
Epithelium, 190 (Gr. *epi*, upon; *thallo*, I bloom). — Cells covering surfaces of animal bodies.
Epithelium in blood, 298.
" *in urine*, 309.
Epithelioma, 293.—A species of cancer.
Epizoa, 330.—Parasitic animals.
Eozoon, 84, 97 (Gr. *eos*, dawn; *zoon*, animal).
Enamel, 192, 197.—Covering of teeth.
Equisetaceæ, 155.—A family of Cryptogams.
Equisetum, 132 —A genus of Equisetaceæ.
Epiphytes, 324.—Parasitic plants.
Epiblast, 202.—Upper layer of blastoderm.
Errors of interpretation, 52.
Ether, 68, 108.
Eosin-staining, 348.
Eolis, 127.
Esophagus, 209 (Gr. *oisophagus*, the throat).
Examination of minerals, 85.
" *of higher plants*, 155.
" *of sputum*, 316.
" *of the air*, 321.
Excretions, 318.—Products of waste or decomposition incapable of further use in the body.
Exudation, 247, 253.
" *corpuscles*, 233.
Exogenous stems, 156 (Gr. *exo*, out, and *gennao*, to grow).—Dicotyledonous plants.
Eyes, care of, 49.
" *of insects*, 176.
Eye-pieces, 26.
Eye-piece micrometer, 38.
Eye-glass, 23.
Fatty tissue, 195.
" *acids*, 184.
" *degeneration*, 233.

Fatty infiltration, 243.
" " *of liver*, 244.
False membranes, 256.
Fermentation, 135.
" *test for sugar*, 306.
Feet of insects, 177.
Ferns, 155, 349.
Fehling's test for sugar, 305.
Fibres, 185.
Fibrillar connective, 194.
Fibrin, 253, 270 (Lat. *fibra*, a fibre).
Fibrinous exudation, 256.
Fibro-cartilage, 195.
Fibroma, 267.—Connective tissue tumor.
" *molluscum*, 268.
Field-glass, 23.
Filaria in blood, 297, 337.
Fission of cells, 125.
Fixed oil in plants, 133.
Flannel, Natural.—Interwoven filaments of Confervæ, resembling coarse cloth, sometimes found in summer on the margins of ponds.
Flatness of field, 55.
Flea, 339. Pulex Irritans.—The last segment of the abdomen of the female, called the pygidium, has disklike areolæ, which is sometimes used as a test-object.
Floscularia, 164.—A genus of Rotatoria.
Flint, 96.
Fluid media, 66.
" *mounting*, 80.
" *cavities in minerals*, 84, 89.
Flowers, 157.
Foraminifera, 95, 159.—Small calcareous shells full of pores or foramina.
Formed Material, 118.—Structure produced by bioplasm.
Fossil plants, 93, 156.
Food, examination of, 323.
Freezing specimens, 228.
" *microtome*, 228.

Fraunhofer's Lines, 44, 101.—Dark lines in the solar spectrum, seen by the spectroscope.

Frog-plate, 41. — The common frog will afford means of studying several kinds of structures. By scraping the roof of the mouth with a scalpel, ciliated epithelium may be obtained (page 191). The circulation of blood may be seen in the foot, mesentery, lung, tongue, etc., by inclosing the frog in a wet bag and extending the tissue over the aperture in the frog-plate (page 187). The ova of the frog are frequently used in the study of embryology, and the transparent parts of the tadpole for observing the development of the tissues.

Fungi, 18, 127, 134, 138, 232, 324.

" *in blood*, 298.

" *in urine*, 311.

Galls.—Abnormal growths on vegetables produced by the sting or eggs of Hymenopterous insects.

Gammarus pulex, 174, 320 (Gr. *gammarou*, a lobster, and Lat. *pulex*, a flea).

Ganglia, 200.—Nervous knots.

Ganglionic Fibres, 199.—Remak's fibres.

Gas-chamber, 42.

Gasteropoda, 170 (Gr. *gaster*, belly; *podes*, feet).—A class of Mollusca.

Gelatinous injections, 71.

" *connective tissue*, 194.

Generative organs, 213.

Generations, alternation of, 126.

Germ-theory, 339.

" *of Dr. Beale*, 340.

Germ-cell, 125.—Ovum.

Germinal Matter, 118, 122.—Another name for bioplasm—living protoplasm or "cell-stuff."

Germinal vesicle, 201.

" *spot*, 201.

" plates, 202.

Germ-fungi, 325.—Gymnomycetes.

Gerlach's carmine injection, 72.

Geology, microscope in, 92.

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Glass-covers, 77.
" *slides*, 77.
Glands of Brunner, 209.—Intestinal glands.
" " *Lieberkuhn*, 209.—Follicles of intestine.
Glandular Fibres, 131.—Woody fibres of Coniferæ.
" *Tissue*, 200.—Gland structure.
" *Epithelium*, 191.—Lining of glands.
Globules, 185.
Glomeruli of kidneys, 212.—Arterial tufts of Malpighi.
Glioma, 277.—Tumor of nerve connective tissue.
Globigerina, 96.—A genus of Foraminifera.
Glycerin, 74, 228.—The sweet principle of fats.
" *and gelatin*, 74.
" *and gum*, 74.
" *mounting*, 80, 228.
Goitre, 287.—Tumor of thyroid gland.
Goadby's solution, 75.
Gold size, 75.
Goniometer, 86.—An instrument for measuring angles of crystals.
Gonozooid, 166.—Sexual zooid of Hydroids.
Graduating diaphragm, 33.
Graafian Follicles, 215.—Follicles of the ovary.
Granules, 185.
Granulation, 262.—Mode of organization after suppuration.
" *tissue*, 262.
Grammataphora test, 57.
Gregarinæ, 330 (Lat. *gregarius*, in flocks).—A family of parasitic Protozoans.
Gundlach's objectives, 346.
" *condenser*, 347.
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Gustatory Cells, 218.—Elements of organs of taste.
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" *of insects*, 175.
" *worms*, 172.
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Haustellum, 177 (Lat. *haustellum*, a sucker).
Hæmatin, 103 (Gr. *haima*, blood).
Heart, 208.
" *in insects*, 178.
Haversian Canals, 196.—Vascular canals in bone.
Hepaticæ, 154.—Liverworts (Gr. *hepar*, the liver).
Hepatic Lobules, 210.—Elemental structures of the liver.
Herapathite, 113.—Iododisulphate of quinia.
Heterologous Formation, 263.—A tumor differing from the tissue it is found in.
Herschel's doublet, 22.
High powers, 55.
Hipparchia Janira, 56.—A species of Lepidoptera.
Histo-chemistry, 185.
Histology, 128, 182 (Gr. *histos*, tissue, and *logos*, discourse).—The science of tissues.
Histological preparations, 224.
Holothuriæ, 168 (Gr. *holos*, the whole, and *thura*, a gate).—An order of Echinodermata.
Holland's triplet, 23.
Homologous Formation, 263.—A tumor similar to the tissue in which it is found.
House-fly, 339.
Huygenian eye-piece, 26
Hydroids, 165 (Gr. *hydor*, water, and *eidos*, resemblance).—A class of Cœlenterata.
Hydrocyanic acid, test for, 107.
Hyperæmia, 246 (Gr. *hyper*, excess; *haima*, the blood).
Hypoblast, 202.—The lower layer of the blastoderm.
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" *dark-ground*, 35.
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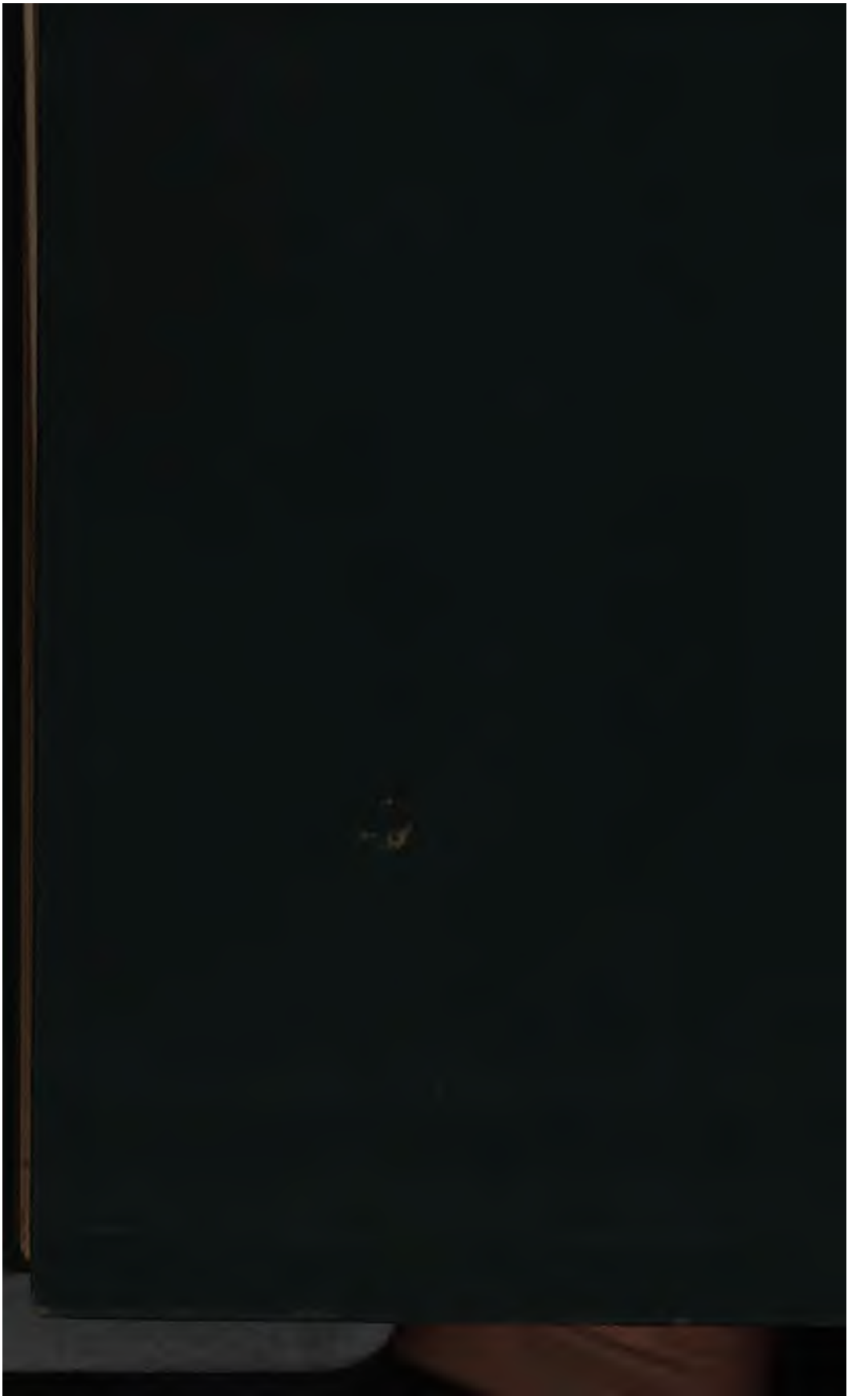
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